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Design of a Power Bus for a New Autonomous Underwater Vehicle (AUV)

by

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13. ABSTRACT

The Naval Postgraduate School had developed its own AUV called the *Phoenix*. A successor of the *Phoenix* is under construction. This new boat, larger, need to have more power than its predecessor to fight the wave current and to have the ability of station keeping in a dynamic environment. In that way, the power capacity will be increased to match and even overtake the range of the first NPS AUV. The *Phoenix* currently uses a 24 volts batteries pack. The new boat will use a 48 volts batteries pack. Moreover, some components will be replaced or removed for the new configuration (camera, acoustic modem, etc...). All this change requires designing a new power bus to give electric power in all the boat. Described in this project is the adaptation of all the *Phoenix*'s components to this new power bus. This adaptation included the choice of new components and the design of the new power bus that will provide energy in the new boat. This project also provides a simulation of the screw motors on Simulink. This simulation, as the beginning of the electric modelization of the boat, provides a complex model of the screw motors. It is simplified at the end to obtain a faster but sufficiently accurate simulation.

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ABSTRACT

The Naval Postgraduate School, as a research laboratory of Autonomous Underwater Vehicles (AUV), had developed its own AUV called the *Phoenix*.

A successor of the *Phoenix* is under construction. This new boat, larger, need to have more power than its predecessor to fight the wave current and to have the ability of station keeping in a dynamic environment, like the *Phoenix*. In that way, the power capacity will be increased to match and even overtake the range of the first NPS AUV.

The *Phoenix* currently uses a 24 volts batteries pack. The new boat will use a 48 volts batteries pack. Moreover, some components will be replaced or removed for the new configuration (camera, acoustic modem, etc...). All this change requires to designing a new power bus to give electric power in all the boat.

Described in this project is the adaptation of all the *Phoenix*'s components to this new power bus. This adaptation includes the choice of new components and the design of the new power bus that will provide energy in the new boat.

To reach this goal, some solutions were possible:

- Put all the voltage level in the center of the boat with each component connected at the same place
- Divided each different voltage level for each part of the boat separately.

The second solution was chosen for its best configuration (connections clearer, no "mess" with the wire...). Thus, this work presents all the steps of the power bus design.

This project also provides a simulation of the screw motors on Simulink. This simulation, as the beginning of the electric modelization of the boat, provides a complex model of the screw motors. It is simplified at the end to obtain a faster but sufficiently accurate simulation.

All this works were planned on Microsoft project 98 which permits to have an efficiency in the scheduling of the different work for the new boat construction.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF ACRONYMS

ADV	Acoustic Doppler Velocimeter
AUV	Autonomous Underwater Vehicles
A/D	Analog/Digital
DC	Direct Current
DGPS	Differential Global Positioning System
GPS	Global Positioning System
ma	milliamp
PSI	Pound Square Inch
RDI	Radio Doppler Velocimeter
ROV	Remotely Operated Vehicles
UUV	Unmanned Underwater Vehicles

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As mechanical engineering student from the "Ecole Nationale d'Ingénieurs de Tarbes", France, I have been given the opportunity to come to Monterey, California for my final project to work in the Mechanical Engineering Department of the Naval Postgraduate School.

First of all, I would like to thank Professor Tony Healey for the unconditional support he gave me throughout this project. His expert experience, perseverance and the confidence he demonstrated towards me permitted my project to be successful.

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I also want to say that this project was a great occasion for me to do my final work as student in a complex research environment that is very different of the manufactoring environments. It has been also a technical and human challenge and I have been glad to accept it.

I. INTRODUCTION

This chapter provides a discussion of the background for the new NPS AUV project and outlines of the scope of study for this project.

A. BACKGROUND

The applications of Autonomous Underwater Vehicles (AUVs) and Remotely Operated Vehicles (ROVs) are subject of increasing widespread interest by both civilian and military organizations. At the present time, Unnamed Underwater Vehicles (UUV) activities in military, scientific and commercial fields are usually performed by ROV's.

The operation of ROVs is traditionally accomplished by the use of a physical tether, through which electrical power, control and sensory data are transferred between the vehicle and a surface ship. ROVs are employed in the offshore oil and gas industries, salvage and recovery, and increasingly, ocean science, as well as in military mine countermeasure operations. An ROV, therefore, is under the continuous control of a human operator (pilot) who provides vehicle motion control by viewing the underwater environment through a video camera for short-range visual feedback.

When deep-water applications or large horizontal movements of a vehicle are necessary, the tether becomes an ever-increasing liability. It adds uncertain and time varying tensile loading on the vehicle, and requires elaborate tether management equipment. These shortcomings, and the associated costs of the support ship, have led to development of AUVs.

An AUV operates independently of any physical or electrical tether (human in the control loop), and requires little to no intervention from an outside activity. This type of vehicle can be well suited for performing expensive and monotonous tasks such as ocean water quality, bathymetry, and geological survey. AUVs might also be utilized for harbor and underwater inspection tasks and most importantly, mine countermeasures and neutralization, where there is a potential for loss of life. Numerous research projects are encompassed in the Autonomous Underwater Vehicle project at the Naval Postgraduate School in Monterey, California, at the Monterey Bay Aquarium Research Institute

(MBARI), Charles Stark Drake Laboratories, amongst others. The primary limitations to widespread AUV usage are economic support and cost effective system integration.

Vital to the accomplishment of the different missions, is the capability for the vehicle to position itself in the vicinity of a stationary object or change its position with respect to an object, within a dynamic environment. The AUVs designed by the NPS are intended to operate in shallow water. Control in shallow water is more difficult due to a higher current than in deep water. The wave effects are not easy to control.

The ability to accurately maneuver itself at relatively low speeds within a confined environment, has been demonstrated by the second-generation design of the NPS AUV (*Phoenix*). The ability to achieve accurate dynamic positioning during hover conditions, based on the vehicle's own acoustic sensor input, has been made possible only recently through several configuration changes to the *Phoenix*.

B. MOTIVATION

The NPS *Phoenix* used a 24 volts batteries pack. To increase the range in relation to the *Phoenix*, the new boat will use a 48 V batteries pack. Moreover, some components will be added or removed to have more current technologies. Thus, a new power bus has to be design for the new boat to adapt all the components to the new voltage level.

This report will outline the design of this new power bus and the first step of an electric modelisation of the new boat in order to know its consumption according to the kind of mission planned.

C. SCOPE OF REPORT

The objective of this project is the design a new power bus for the new AUV. In fact the most important difference between the *Phoenix* and the new boat, (aside from a new hull), is the modification from 24 volts to 48 volts. This change requires a complete adaptation of the sensors and the actuators. Moreover, the new idea for this boat is to put circuit breaker instead of the traditional fuse, and, magnetic switch (to switch on or off some components) accessible from the outside of the hull. With circuit breaker with

visualization of theirs conditions, you can easily see where the problem is when it occurs. One of other change is to replace feed through terminals by plug for an easy replacement of components (test, experimentation, and problems) and an easy use.

Chapter III provides documentation of the major design and configuration changing, incorporated into the new boat, which provide the capability for the vehicle to accomplish the hover positioning experiments.

Chapter IV describes component choices. This is a description of problem encountered, the test experiments are also discussed.

Chapter V is the presentation of the motor simulation on MATLAB Simulink. This model is the first step to an electric modelization of the new boat.

Chapter VI describes the scheduling of the new boat construction.

Chapter VII is conclusions and recommendations.

II. RELATED WORK

A. INTRODUCTION

Research on Autonomous Underwater Vehicles has been an ongoing project at the Naval Postgraduate School (NPS) of Monterey since 1987 through the *Phoenix* project [Healey 90,92] [Brutzman 96]. This vehicle is a student research testbed for shallow water minefield mapping missions. The *Phoenix* is also intended to demonstrate that there are no fundamental technical impediments to realize this kind of task using affordable underwater robots. Its design has to be robust and has a low cost.

This chapter is a general overview of the frame of this study, the NPS AUV. It provides a description of the hardware and the software architecture of this vehicle.

B. AUV PHOENIX PRESENTATION

1. Physical Description

The new boat is very similar at the *Phoenix*. For example the same sensor will be use (RDI, ADV, Sonars), the global shape has been conserved, it will also use thrusters and propellers for its motion. Thus, a description of the *Phoenix* is done in the next paragraph.

The Naval Postgraduate School *Phoenix* AUV is approximately 2.4 meter long, 0.46 meter wide and 0.31 meter deep. It has the shape of a miniature submarine with two aft propellers, two vertical thrusters, two horizontal thrusters, one or two fore rudders (the upper one is sometimes removed), two aft rudders, two fore fins and two aft fins to control its movement through the water.

The AUV has a 2 psi pressurized aluminum hull with a free-flooding nose cone that houses some of the AUV's measurement devices. The vehicle is designed to be neutrally buoyant at three hundred and eighty seven pounds with a designed depth at twenty feet. Lead acid batteries providing endurance up to two hours electrically power the submarine. Changes on the new vehicle are presented in paragraph C.

For the survey and mine countermeasure purposes mentioned above, several devices have been installed in the AUV; some are intended for navigation and others are used for measurements.

The following list details these pieces of hardware and their purposes:

- Four sonars:
  - Overall environmental sensing (ST 725 model),
  - Obstacle classification (ST 1000 model),
  - RDI Doppler sonar for the speed over the ground,
  - Sontek ADV for water particle relative velocities (U,V,W),
- A GesPac computer for controlling the AUV's stability, *execution* level of software. It will be no longer use. It will be replaced by a PC104,
- A Sun Sparc 5 computer for data storage and running *strategic* and *tactical* levels of software, also replaced by a PC 104,
- GPS and DGPS for tracking the vehicle latitude and longitude,
- DiveTracker for precision tracking (not used at present),
- System donner for sensing the vehicle's orientation by measuring angles and rates for roll, pitch and yaw respectively. They will be also put out in the new boat,
- A depth cell,
- A/D and D/A converters for computer hardware interfaces,
- Lead-acid batteries for power supply. The new batteries pack will be a 48 V,
- A TMC2 compass.

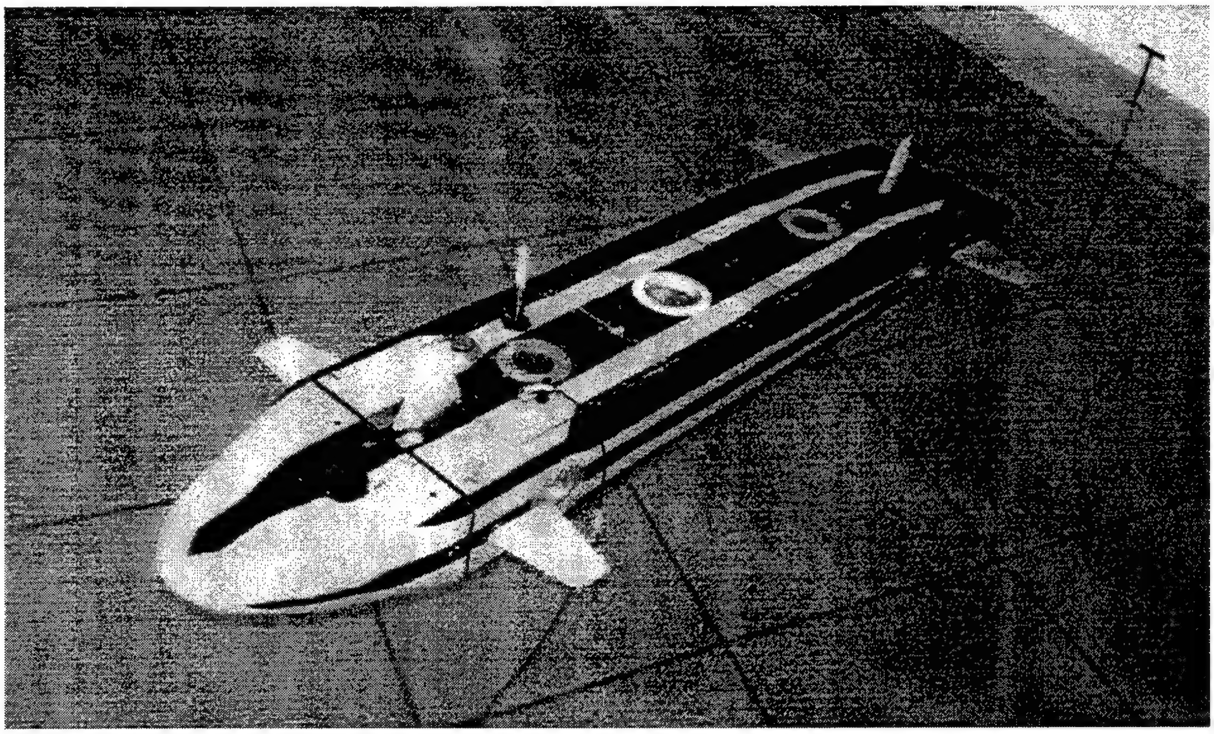


Figure II-1: *Phoenix* AUV undergoing testing at the Center for AUV Research (CAUVR) laboratory test tank in early 1995.

2. Software Description

The *Phoenix* AUV has used a tri-level software architecture called the Rational Behavior Model (RBM). RBM divides responsibilities into areas of open-ended strategic planning, soft real time tactical analysis, and hard real time execution level control. The RBM architecture has been created as a model of a manned submarine operational structure. The correspondence between the three levels and a submarine crew is shown in the Figure II-2:

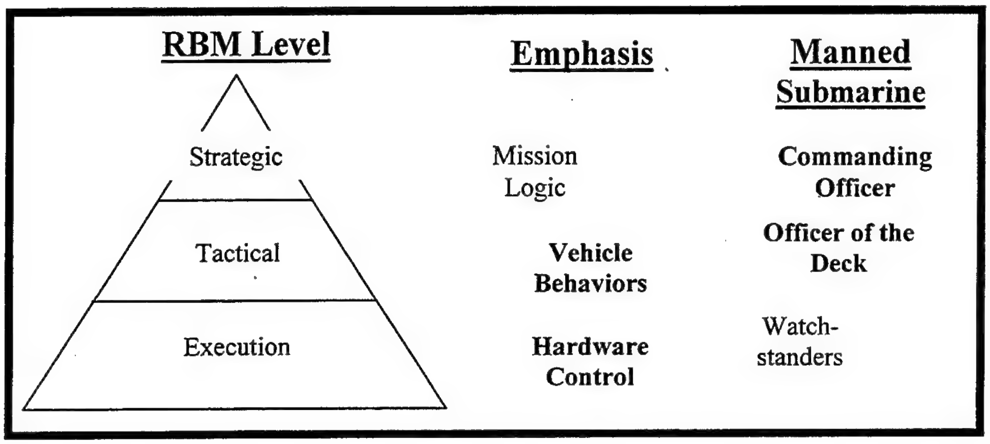


Figure II-2: Relational Behavior Model tri-level architecture hierarchy with level emphasis and submarine equivalent listed [Holden 95].

The **Execution Level** assures the interface between hardware and software. Its tasks are to underlay the stability of the vehicle, to control the individual devices, and to provide data to the tactical level.

The **Tactical Level** provides a software level that interfaces with both the Execution level and the Strategic level. Its chores are to give to the Strategic level indications of vehicle state, completed tasks and execution level commands. The Tactical level selects the tasks needed to reach the goal imposed by the Strategic level. It operates in terms of discrete events.

The **Strategic Level** controls the completion of the mission goals. The mission specifications are inside this level.

C. NEW AUV DESCRIPTION

In order to increase the range and capabilities of the boat, a new NPS AUV is being manufactured.

This new boat is very similar to *Phoenix*. Actually the global shape for both hardware and software has been maintained. The main difference stands in the addition of two ballast chambers and the increase of the power capacity. The new vehicle will use a 48 Volts batteries pack instead of a 24 Volts batteries pack. The goal of the ballast chamber is to enable the AUV to sit on the ocean's bottom in a mechanical way (by making it heavier) without consuming a lot of power.

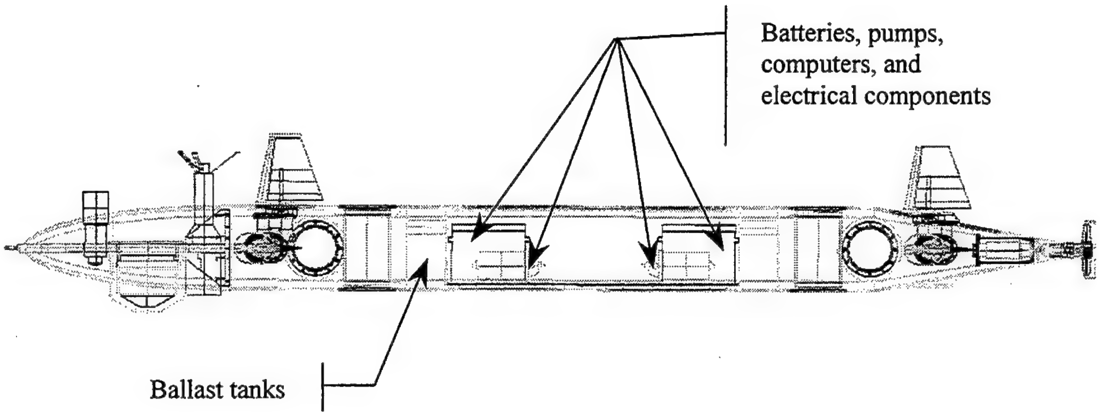


Figure II-3: New NPS AUV side view [Garibal, 1999]

Furthermore, two Pentium processors are planned to be used to provide strategic, tactical and execution level control. They are faster and cost less power than the GESPAC combined to a Pentium processor used on the *Phœnix* AUV.

D. SUMMARY

This chapter presents the characteristic of the *Phoenix* and the difference between it and the new boat. The new boat will be described with accuracy in chapter III

III. POWER BUS DESIGN

A. INTRODUCTION

This chapter provides a description of the major equipment groups that comprise the new configuration of the NPS AUV. Each section discusses the nominal operating characteristics and ratings as applicable, and refers to figures within the text. Additionnal diagrams and the wiring list are included in the Appendix A.

B. GLOBAL PRESENTATION

Since the time of its original design (Good, 1989) and successful waterborne demonstration (Warnner, 1991), several design and configuration concepts have been the subject of research surrounding the AUV project at the NPS, resulting in numerous published theses. Riedel, 1999, demonstrated the ability for the *Phoenix* to keep position on the surface despite the wave current employ a Kalman filter. The following equipment groups are discussed:

- Sensors (Environment and vehicle)
- 2 PC 104 (Computer system : execution level and tactical level)
- Propulsion and maneuvering system
- Electrical power requirement

A simplified block diagram of these major equipment groups is provided in Figure IV-8 showing the basic system power paths between the component.

Figure III-1 shows the placement of the major equipment in the *Phoenix* AUV. The new placement will be close to *Phoenix* component's placement. The propulsion and maneuvering equipment (control fins, tunnel thrusters and stern motors) is arranged in the vehicle to achieve the most efficient maneuvering capabilities. The remainder of the equipment is located to achieve the most favorable volume and weight distribution, and to minimize the length of the wire runs. The batteries therefore, are centrally located in order to keep the center of gravity close to the center of the vehicle body. The two computers are located at the center of the vehicle body, with the served equipment located as close as possible to the computers.

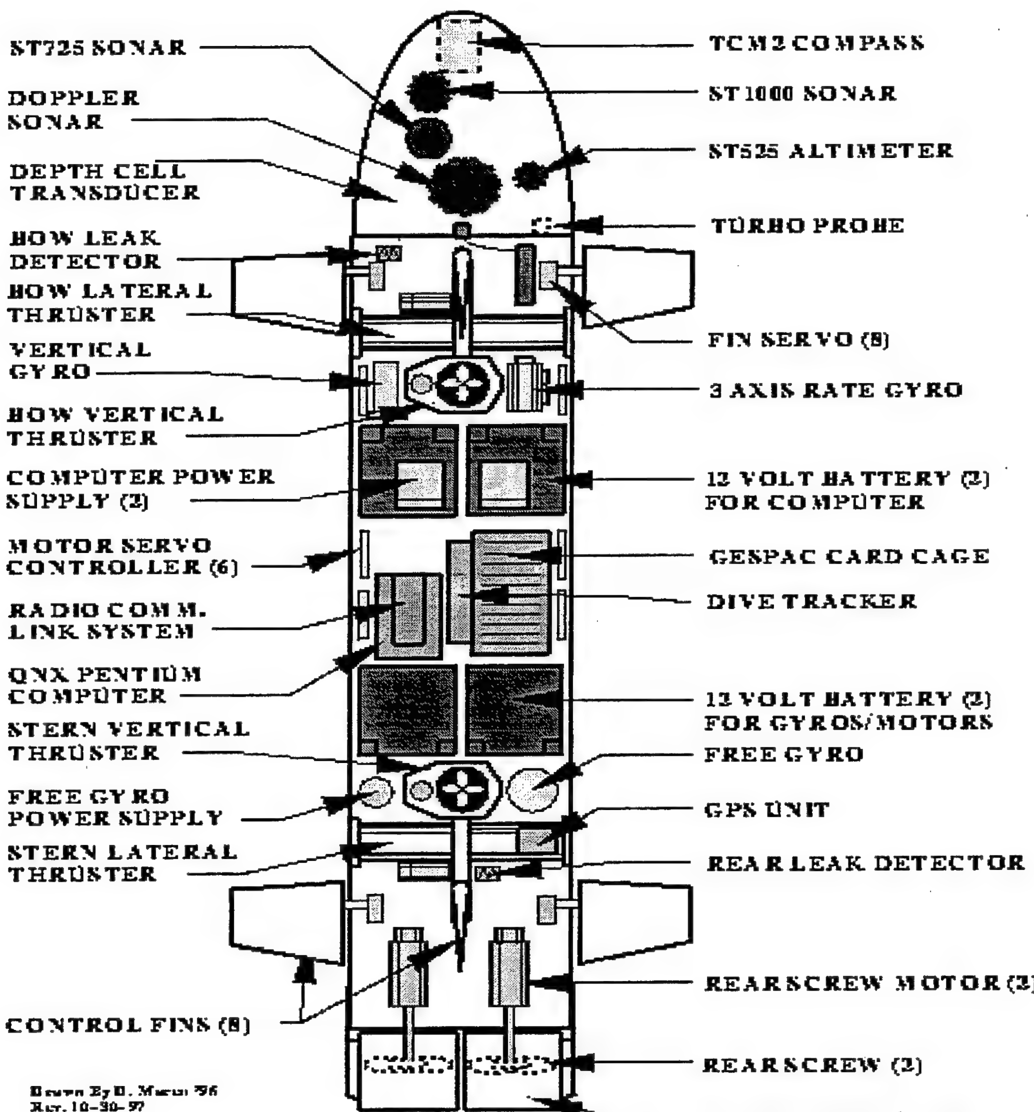


Figure III-1: Placement of the component in the AUV Phoenix [Dave Marco, 1996]

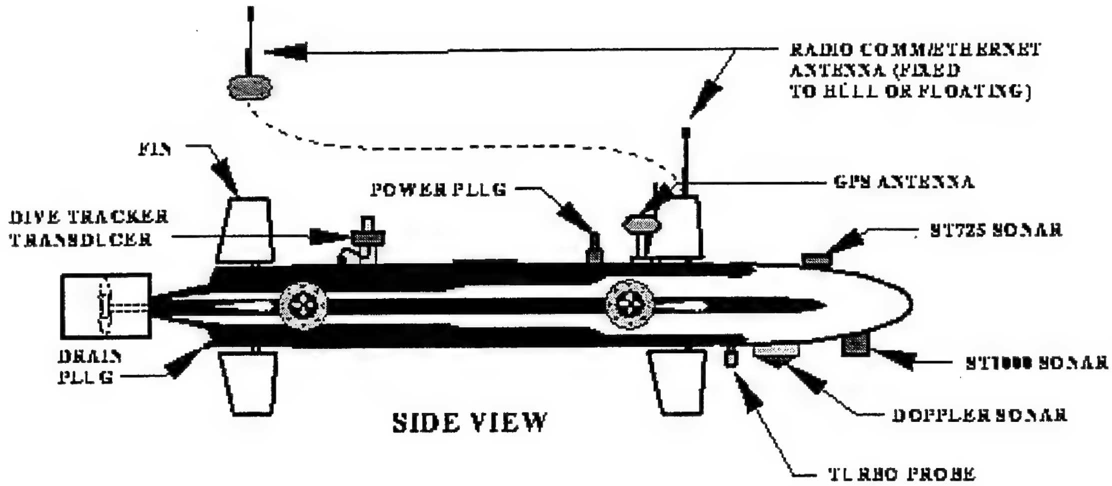


Figure III-2: Side view of the AUV Phoenix [Dave Marco, 1997]

Calculations of the center of gravity and buoyancy are provided by the studies presented in [Garibal, 1999].

C. SENSORS

The sensor systems that will be incorporated into the new AUV is practically the same than in the *Phoenix*. It provides the necessary input data for both environment conditions and vehicle motion, to achieve autonomous vehicle operations and control. The sensors that are no longer used in the new boat are TMC2 compass, all the gyroscopes and the turbo probe.

A summary of sensors follows.

1. Environment Sensors (Sonar Equipment)

The environment sensors consist of two types of sonar transducers: The Tritech ST1000 with primary function being horizontal environmental surveying (profiling) and the Tritech ST725 sonar for target imaging (scanning).

The others components will be add in an imminent future are:

- Camera will provide an image of the robot environment
- Acoustic modem for the underwater data transmissions.

Placement of the transducers, in the flooded nosepiece section of the new AUV is almost the same than in the Phoenix.

a. *Profiling Sonar (Tritech ST-1000)*

The profiler is the model ST-1000 sonar, manufactured by Tritech international, Ltd. This unit is a compact system, operated by a PC compatible computer and is integrated with the ST-725 scanning sonar.

The ST-1000 head operates at a frequency of 1250 kilohertz (1000 kilohertz, nominal), with a one degree conical beam. It requires 24 to 28 volt DC power for 300 milliamps, and can be operated at depths up to 4900 feet, over eight selectable ranges between three and 160 feet.

The ST-1000 can be operated in two modes: Sector Profiling or Sector Sonar Scanning. The profiling mode provides 360 degrees coverage, where the delay time to the first echo is sensed and returned to the device serial port connector. The scanning mode is continuous, and can be used for horizontal sector scan, or for vertical left or right side direction coverage. In this mode, the intensity of the returning echoes are sensed as a function of delay time and returned to the device serial port connector as a string of values, one in each of 64 range pixels. At larger total ranges, full range is divided into 128 range pixels, For the shorter ranges, a sonar pixel will be 9.3 centimeters long by 1.8 degree wide. Intensities are scaled from one to 15, where 15 represents the highest strength.

The ST-1000 sonar head will be mounted vertically, in the new AUV, protruding through the bottom of the nosepiece.

Figure III-3: Picture of the Tritech sonar ST 1000 [Tritech, 1999].

b. Scanning Sonar (Tritech ST-725):

The scanning sonar is the ST-725, also manufactured by Tritech. It operates at a frequency of 725 Kilohertz with a one degree by 24 degree fan beam.

The ST-725 sonar head is mounted aft of the ST-1000, but protruding through the top of the nosepiece.

Figure III-4: Picture of the Tritech sonar ST 725 [Tritech, 1999].

2. Vehicle Sensors

The vehicle sensor components provide the input data for the position and motion of the AUV.

a. RDI (Radio Doppler Velocimeter):

The RDI, manufactured by RD Instruments, measures the boat speed in relation to the bottom. It operates at a frequency of 2 Kilohertz for a consumption of 8 watts.

The RDI is mounted vertically, in the new AUV, protruding through the bottom of the nosepiece.

Figure III-5: Picture of the RDI [RD Instrument, 1999]

b. ADV (Acoustic Doppler Velocimeter):

The Acoustic Doppler Velocimeter manufactured by SonTek is a versatile, high-precision instrument used to measure 3D water velocity. Fused together with Doppler velocity log data, it provides water particle velocity information to the vehicle's control systems. In addition, the ADV's installed optional compass provides a backup to the vehicle's Inertial Motion Package. But the compass is not use in our application. The ADV is designed for a wide range of environments, including the surf zone, open ocean, rivers, lakes, and estuaries. Its operates at a frequency of 8 Kilohertz.

It uses acoustic Doppler technology to measure 3D flow in a small sampling volume located a fixed distance (18 cm) from the probe. The velocity range is programmable from ±5 to ±500 cm/s.

The ADVOcean processor operates from external DC power (24 V@210mA) and outputs data using serial communication or a set of analog voltages. The processor can be operated from any PC compatible computer or can be integrated with a variety of data acquisition systems.

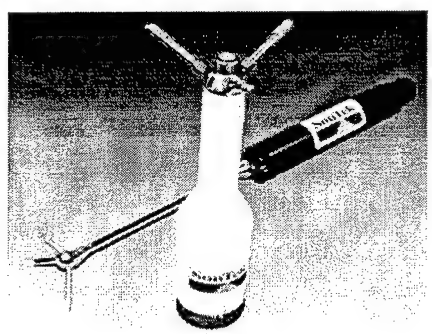


Figure III-6: Picture of the ADV [Sontek, 1999]

c. Depth Cell (PSI- Tronix):

Vehicle depth is measured using a differential pressure transducer manufactured by PSI-Tronix, Inc.

The PWC series (S11-131) is a stain gage based transducer that operates from zero to 15 pounds per square inch (depth to approximately 34 feet), referenced to one atmosphere. It requires 12 to 18 volts DC supply and outputs zero to 10 volts DC.

The probe for the depth cell is located in the nosepiece section of the vehicle in the aft bulkhead, in order to permit contact with the water at the vehicle's depth, with minimal flow.

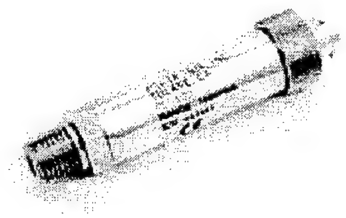


Figure III-7: Picture of the depth cell [PSI Tronix, 1999]

d. GPS:

The new boat will use DGPS and GPS information to update its position at every come back to the sea surface. The GPS use is the GPS VPONCORE manufactured by MOTOROLA.

It requires 12 volts for a consumption of 1.8 Watts.

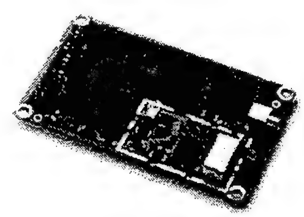


Figure III-8: Picture of the GPS VP ONCORE [MOTOROLA,1999]

e. Freewave modem

The Freewave wireless data transceivers is linked to the differential receiver to receive and transmit the GPS data.

It requires 12 volts for an average current of 180 mA.

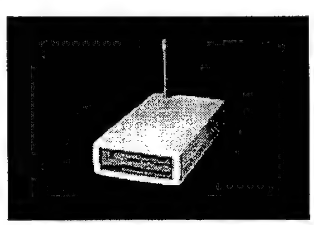


Figure III-9: Freewave modem [Freewave, 1999]

f. Motion pack:

The Motion pack is a "solid-state" six-degree of freedom inertial sensing system uses for measuring linear accelerations and angular rates. It is a highly reliable, compact, and fully self-contained motion measurement package. It uses three orthogonally mounted "solid-state" micromachined quartz angular rate sensors, three high performances linear servo accelerometers mounted in a rugged package, internal power regulation and signal conditioning electronics.

The power requirement is positive and negative 15 V for an input power of 7 Watts.

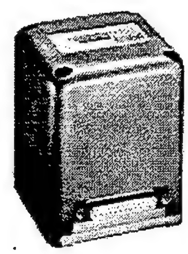


Figure III-10: Motion Pak [BEI, 1999]

PROPULSION / MANEUVERING EQUIPMENT

The propulsion and maneuvering systems are comprised of three groups of equipment: Control surface servos, stern propulsion and thrusters.

3. Control Surface Servo

The development of the design of the control surfaces is presented in Good (1989).

Two cruciform arrangements of control surfaces are used: one arrangement forward and one aft, on the mibody section of the AUV. This arrangement provides highly efficient maneuvering capability in both the horizontal and vertical planes as evidenced by previous waterborne testing of the AUV [Healey and Marco, 1992]. The new boat does not have the bottom fin in the forward and in the aft of the boat.

The control surfaces are positioned through the use of radio controlled aircraft servo motors HITEC model HS805BB servos are installed, one for each control surface. These motors have a maximum torque rating of 19.8 kg.cm (275 oz-inches) at 4.8 V, and a response time of 0.19 second for a 0 to 60 degree movement. They require 5V.

4. Stern Propulsion

The new AUV, like the *Phoenix*, will be configured with a conventional twin screw propulsion system. The new propellers, four blades, four inch diameter will be installed, each capable of providing 10 pounds of thrust at 0.7 R at full load.

Electric DC servo motor, model BE30A8, manufactured by Advanced Motion Control will be used for the stern propulsion units. The PITTMAN DC brushless motors, model GM5143 have a stall torque of 1.56 N.m, a no load speed of 278 radians per second and a peak power of 300 Watts. Operating at a reference voltage of 17 volts DC, the motor has a no load current rating of 0.152 Amps.

5. Thrusters

The new AUV will use new thrusters especially manufactured for AUV or ROV. Tecnadyne manufactures these DC thrusters, model 250, have power and control housed within motor case. They require 48 V at 6 Amps for an input power of 300 Watts.

Moreover, they need + 12 volts for electronics power.

D. ELECTRICAL POWER EQUIPMENT

The objective of the new AUV design considerations for the power requirements was to provide adequate energy onboard which would support all vehicle function for at least 3 hours of completely autonomous operations (Cf. AUV estimation working time).

The new electrical system will provide enough power to run the vehicle's onboard computers, sonars and electronics systems in addition to power for mobility.

This section describes the major components of the electrical power systems.

1. 48 Volts Battery Pack (Lifeline)

Four 12 Volts DC batteries, connected together, provide the main power sources (48V) for the new AUV. Each batteries is a 12 V DC, manufactured by Lifeline, model GPL-U1.

Batteries packs provides 48 V DC power to the followings equipment:

- ACON computer power supplier.
- Servo Amplifiers BE30A8 (Thrusters and stern propulsion motors)
- DC thrusters model 250
- RDI
- Calex power Supplies

The batteries packs (2 x 24 V) are located in the midbody section of the AUV, one forward and one aft of the two PC104.

2. ACON Power Supplies

Two ACON model R100T4805-12T2 inverter/power supplies are installed to provide power for computer system. The two power system are independent and provide positive five and negative to positive 12 volts (DC).

3. Calex Power Supplies

The Calex models 48S24.3HE, 48S5.15SW, 48S12.500, 48S5.8HE, 48S5.1000 provide the power to the different components:

- + 24 V DC for the RDI and the two sonar
- + and – 15 V DC for the motion pack and the depth cell.
- + 12 V for the GPS and freewave modems
- + 5 V for the control surface servo
- + 5 V for the main power relay and the magnetic switch.

4. Circuit Breakers

The idea, for the new boat, is to have a robot simply to use. In this way, a can accessible from outside the hull with magnetic switches was built. These magnetic switches replace the plug, which is currently use in the Phoenix. This magnetic switch system will turn on and off, separately, the main power relay, the sensors (RDI, ADV, and SONAR…). After on the main power bus the classic fuse will be replace by push to reset breaker. These thermal circuit breakers have a visible trip indicator, which permits to have a fast, an easier view of where the problem is when a circuit breaker switch off a component.

There is to kind of circuit breaker from Siemens:

- The W58 series (appendix B) with a maximum operating voltage 50VDC and a 1 to 8 A rating.
- The W23 series with the same specification for high load current (up to 40A)

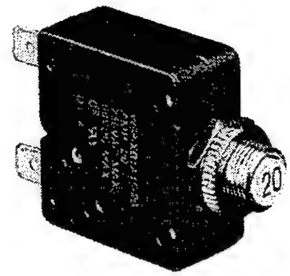


Figure III-11: Picture of the thermal circuit breaker [Siemens,1999]

5. Plug

To facility the change of component in the new AUV, a case with all the current voltage need in the AUV will be put. This case will be place in the midbody of the new AUV (2 cases), in the aft and in the screw.

These cases have a plug for each voltage level with a fuse appropriate to the component. This plug are built for 50 V up to 12 A.

6. Relays

In relation with the magnetic switch, we need relays to put on and off the power in some components that are not need for all the missions (Sonar, ADV, RDI, GPS). This relays, manufactured by GORDOS, can be use between and with a command range of 3 to 8 V DC.

7. Servo Amplifiers (Advanced Motion Control)

Motor speed for the thruster and stern propulsion is controlled through the use of Advanced Motion Control servo amplifier, model BE30A8. One Amplifier is use for each motor. They are connected directly to 48 volts and use a -5 to +5 volts control signal to modulate the pulse width of 24 volts, five to forty five kilohertz output signal.

They are located in the side of the boat (the same number in each side).

E. SUMMARY

This chapter is a summary of all the main components that will be put in the new AUV. The main characteristic are described in detail for each component.

IV. COMPONENT SELECTION

A. INTRODUCTION

This chapter provides a description of how the equipment was selected according to the main goal, which is a facility of component changing and also according to the problems encountered during the design.

B. PRESENTATION

On the *Phoenix*, there was not a real power system: All the components were placed where there was place. So, the idea, for the new boat is to have a power system easy to use for experiments. Easy to use means:

- Easily accessible: in fact, components of the new boat must be connected or disconnected rapidly and easily,
- The idea is to replace the feed through terminals (screw terminals) by plugs. These plugs will be placed in the front, the middle and the screw of the robot. Thus, the power is available in all the part of the robot. All the components are also placed on board for a fast changing of them,
- Simplicity of use: for example, when you have a problem on a component, a fuse protects it. But, sometimes, it's difficult to replace it because of the access. By replacing the fuse by a circuit breaker put on a panel with visualization trip of its condition, you can determinate where the problem occurred and solve it fast.

The last change is the magnetic switch system that replaces the plug. That protrudes through the hull. Theses magnetic switches will be placed under a Plexiglas glass for activation and visualization on the exterior of the hull (thanks to LED). Its permits to switch on and off some components and the main power relay just by approach a magnet near the switch.

The scheme below show how the new power bus will be:

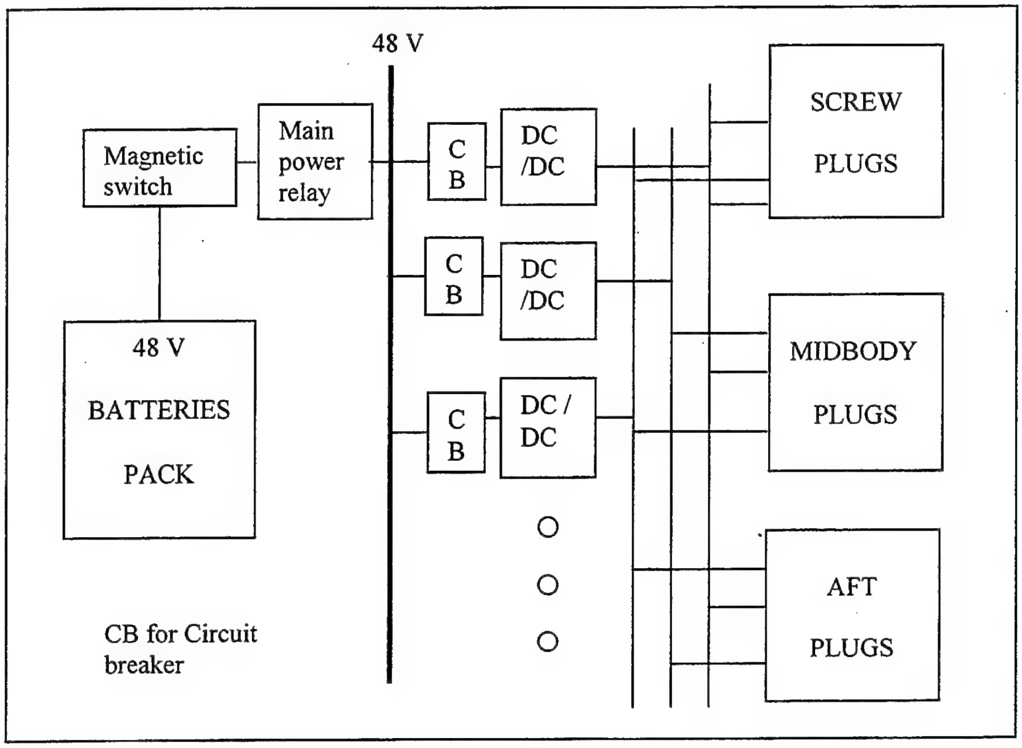


Figure IV-1: Main scheme of the new power bus

The constraint are:

- The first is the place. In fact, there is not so much place so the smallest components must be chosen.
- The price of course
- The compatibility between the component. This part is divided for each component.
- The new 48 V power.
- The magnetic switch system (TTL technologies).

C. WORK

1. Motor Wiring:

Connecting a brushless DC motor and a servo amplifier made by different manufacturers can often be confusing. One reason is that no industry standard exists for labeling the three motor phases. In fact, to work correctly, a brushless motor need a perfect command. This command is realized thanks to a servo amplifier that gives the power to the different motor phases. (See page 37 to know how a brushless motor works)

The BE30A Series PWM (Pulse Width Modulation) servo amplifiers require only a single unregulated DC power supply between 20 and 80 V. So the 48 V is put directly to the input of the DC/DC converter. A circuit breaker protects the motor system.

In our case, the servo amplifier encoder part is not use, in fact, the encoder of the motor will be directly connected to the computer that will read and match the speed to the speed required for the command.

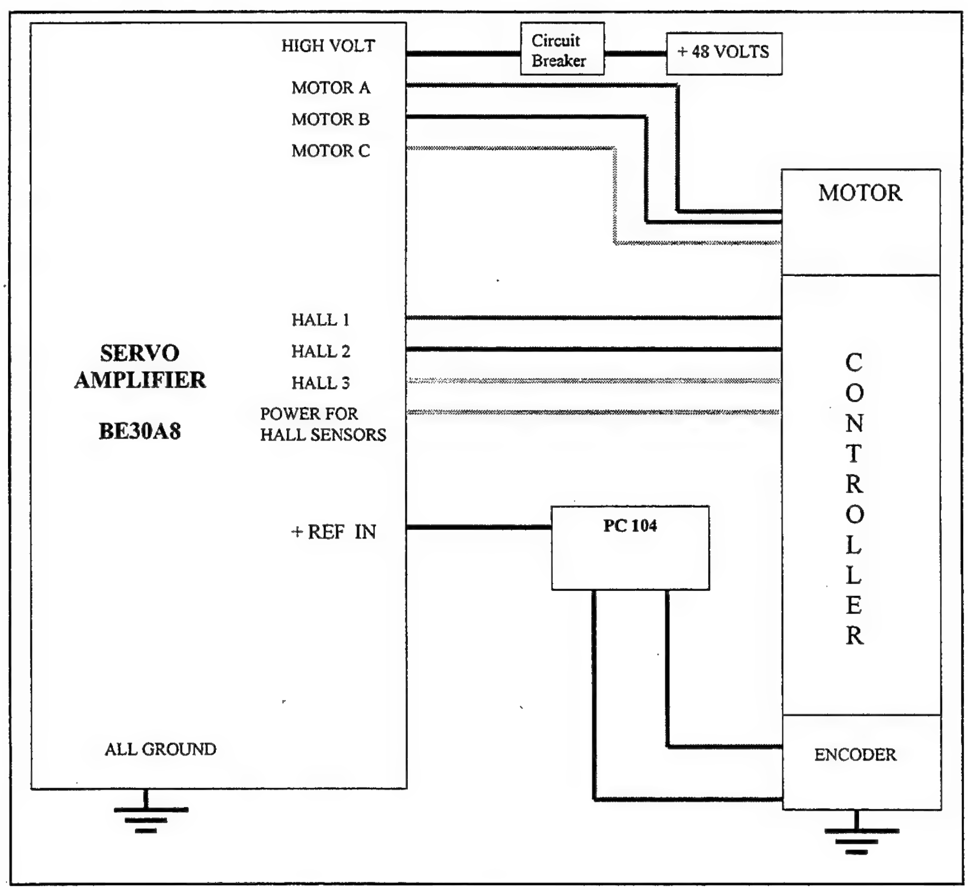


Figure IV-2: Motor wiring

The more important tune made on the servo amplifiers are:

- Switches: They permit to choose the running mode (Current, encoder velocity, and open loop). For this application, a voltage control has to be done. So the servo amplifier were configured for an *Open loop mode*. With this mode, the reference-input voltage commands a proportional motor voltage (by changing the duty cycle of the output switching). This mode is not a closed loop configuration. The average output voltage is a function of the power supply voltage. They also permit to choose the degree of the phase (60 or 120) and to make some tune on the current.

- Potentiometers: They permit to adjust with accuracy the current and the gain of the loop.

So, the motor was connected and the servo amplifiers adjusted to match the performance of the motor.

2. Main Power Bus

The second step was to design the main power bus. For this work, a list of the component that would be put on the new boat was made. This list refer to the name of the component, theirs typical consumption, voltage. This list permitted to know how much power is needed to choose the main power relay. It also permitted to know the range of the new boat, which is calculated on the next page. This list is available in appendix A.

Assumptions:

The four batteries (connect in series) have rates of 35 amps per.hour each under 48V or **1680 Watts.**

During the missions, the boat will only use one sonar between the ST1000 and the ST725, not the both in the same time.
The control surface servo consumption is 3 watt and 2 watts for the electronic power for thrusters. So the hotel load is 67.23 Watts and the thruster load is 300Watt.

Estimation:

To know the range of the new boat, an estimation of the consumption need to be done for different case of running. This estimation is made in the following calculations which estimate the range (in hours) according to the level of consumption.

- With load current: (2 PC104, RDI, and Sonar…)

Consumption: 67.23 W

Power: 1680 W

$\longrightarrow$ 24.98 hours or **24 h 58 mn**

- In extreme case (Load current and all the actuators)

Consumption: 704.83W

Power: 1680 W

$\longrightarrow$ 2.38 hours or **2 h 22 mn**

- Medium case (load current + Screw motor)

Consumption: 367.23 W

Power: 1680 W

$\longrightarrow$ 4.57 hours or **4 h 35 mn**

- With fin servo:

Consumption: 397.23 W

Power: 1680 W

$\longrightarrow$ 4.22 hours or **4 h 14 mn**

These calculations are available in appendix A.

So the range is: Speed x Time

1.2 m/s x 4.57 x (3600 / 1000) = 19.74 Km

This range is very confortable because the AUV operates in shallow water so, close of the shore.

I also realized a model of this motor for a simulation of theirs consumption (cf. chapterV).

a. Main power relay

At the beginning of the design, numerous ways appears. The first concerns the type of the relay. The electromechanical relay seems to be the best solution for the main power relay that will switch on and off the power in the new boat.

The reasons for this choice are:

- No problem caused by high voltage feed through terminal that may occurs from the ignition.
- No frequency to respect for the switch on and off. In fact, this relay switches on the power at the start of missions and switch off at the end. So we don't need a high frequency relay.

But the research on an electromechanical relay for 48 V up to 40 A were unsuccessful. This type of relay is not build for current over 30 amps.

Like the current is around 40 amps, the choice went to use a solid state relay TTL compatible that handles 0 to 100 V DC at up 40 amps.

This relay has a MOSFET technology for low current. It requires 3.5 to 32 V DC for a maximum input current of 1.6 mA at 5VDC. To command this relay, a magnetic switch system will be used. But for the magnetic switch, a TTL compatible technology need to be used.

The TTL technology requires a very small current near 100 milliamps. So I have to use a supplier with a very small current.

At this step of the design, two solutions can be considered:

- Use a DC/DC converter
- Use a linear circuit.

The following table gives the advantages and the disadvantages of the both solutions.

Linear circuit:

ADVANTAGE	DISAVANTAGE
Cheap Voltage regulator	Difficult to replace (need construction of the circuit) Become heat with if there is a big load current (risk of explosion)

DC/DC converter:

ADVANTAGE	DISAVANTAGE
Expensive Stay cool	Easy to replace (board) No voltage regulation

So, to have a real idea of the best solution, they will be compared during tests that will be presented later.

The following pages explain the functioning of the linear circuit:

This linear circuit is the LM 317A, that is a 3 terminals adjustable positive voltage regulator capable of supplying in excess of 1.5 A over a 1.2 V to 37 V output range. Here 5V is necessary with a small current (around 100 mA) in input.

With this circuit, you need only two external resistors to set the output voltage. Further, both line and load regulation are better than standard fixed regulators.

This series offer a full overload protection available only in IC's, included on the chip are current limit, thermal overload protection circuitry remains fully functional even if the adjustment terminal is disconnected.

In that case, an input bypass is necessary. In fact, the device is situated more than 6 inches from the input filter capacitors. So, an input bypass capacitor is recommended to improve transient response.

To regulate the current with accuracy, a fixed resistor is connected between the adjustment pin and the output.

In operation, the LM317 develops a nominal 1.25V reference voltage Vref between the output and adjustment terminal.

The reference voltage is impressed across program resistors R1 and, since the voltage is constant, a constant current I1 then flows through the output set resistor R2 giving an output voltage of:

$$\mathbf{Vout = Vref\ (1 + (R2/\ R1)) + I\ adj\ R2}$$

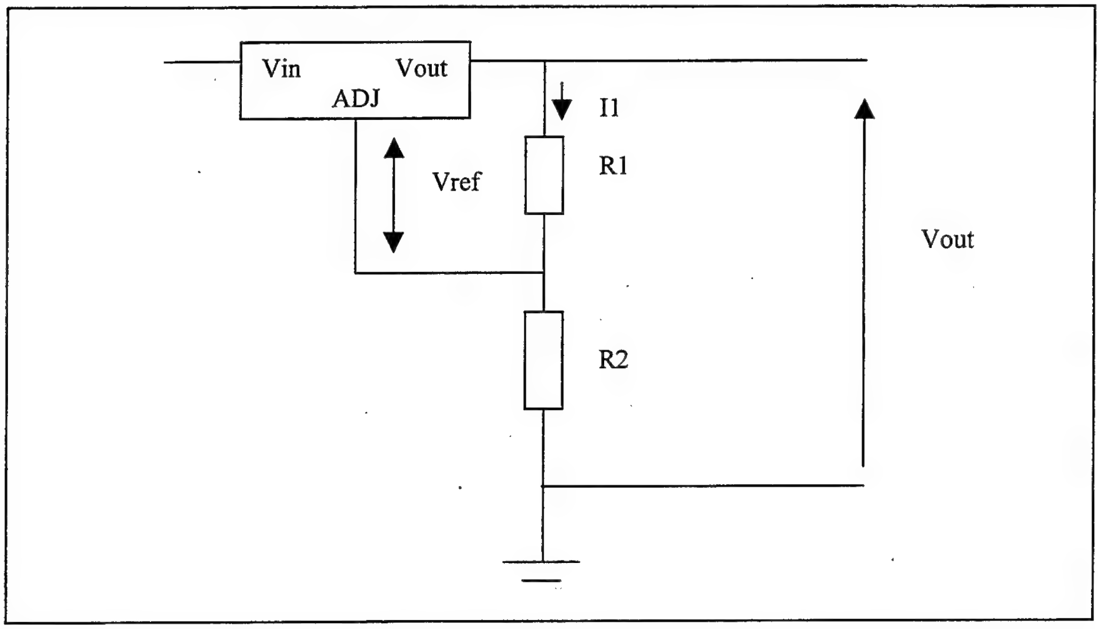


Figure IV-3: Typical voltage regulation with linear circuit.

Since, the 10 micro amps current from the adjustment terminal represents an error term, the LM317 was designed to minimize Iadj and make it very constant with line and load changes. To do this, all quiescent operating current is returned to the output establishing a minimum load current requirement. If there is insufficient load on the output, the output will rise.

The resistor R2 that bypassed the adjustment terminal to the ground improves ripple rejection.

The load regulation:

The LM317 provides extremely good load regulation but few precautions must be taken to obtain maximum performance. The current set resistors, connected

between the adjustment terminals and the output terminal (usually 240 Ω), should be tied directly to the output case of the regulator rather than near the load.

The LM317 regulators have internal thermal shut down to protect the device from over heating. Under all operating conditions, the junction temperature of the LM317 must be within the range of 0 to 125 degree Celsius.

So the new scheme is:

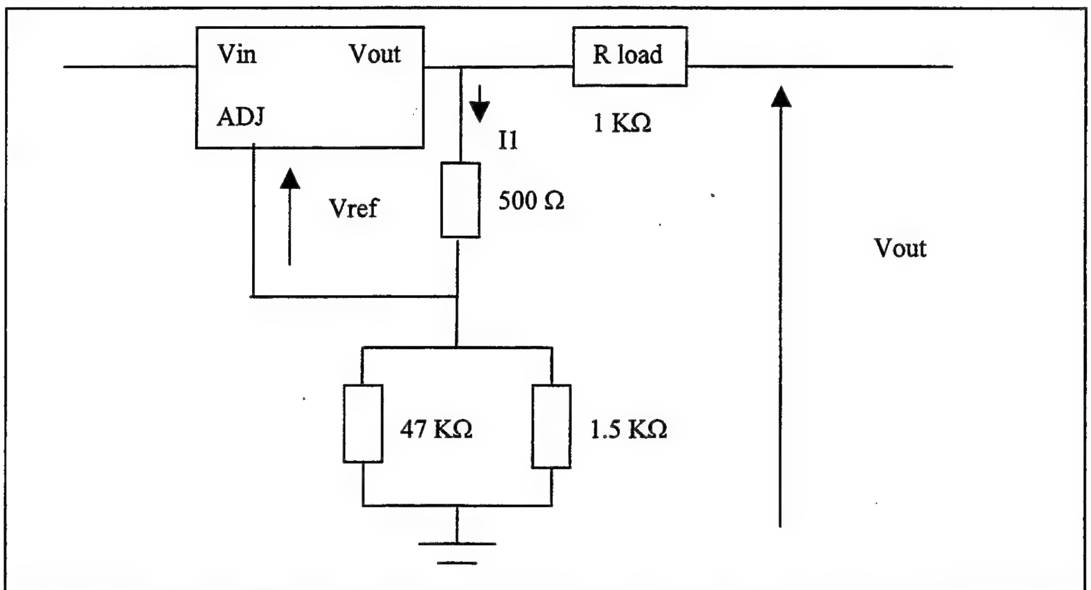


Figure IV-4: 48V to 5V converter thanks to a linear circuit

This circuit can be put on a plastic board with the main power relay and the main fuse breaker. This board is shown on the picture below.

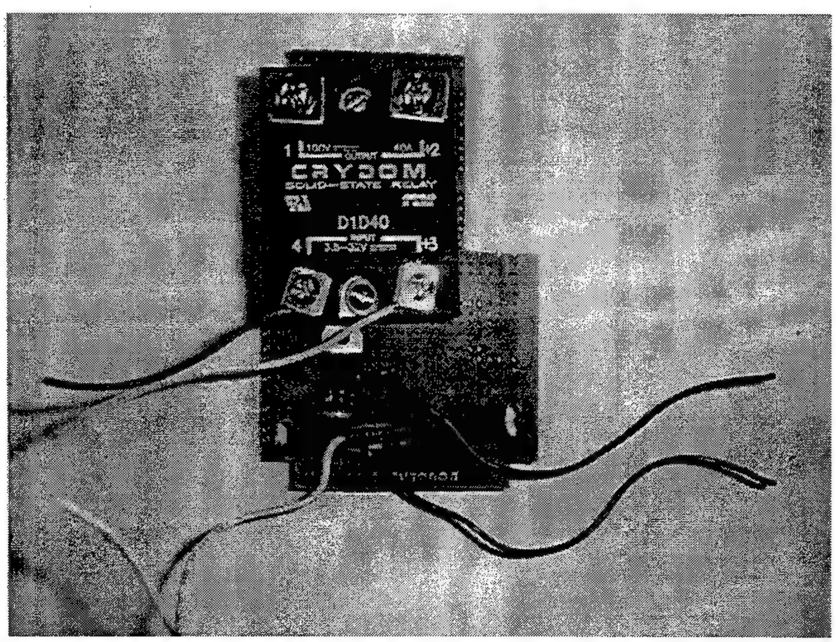


Figure IV-5: Final circuit with the linear circuit

The other solution with DC/DC converter doesn't need explanation. In fact, the DC/DC converter gives 5 volts that power the magnetic switch system and the relays.

The both solutions can be connected in the same way:

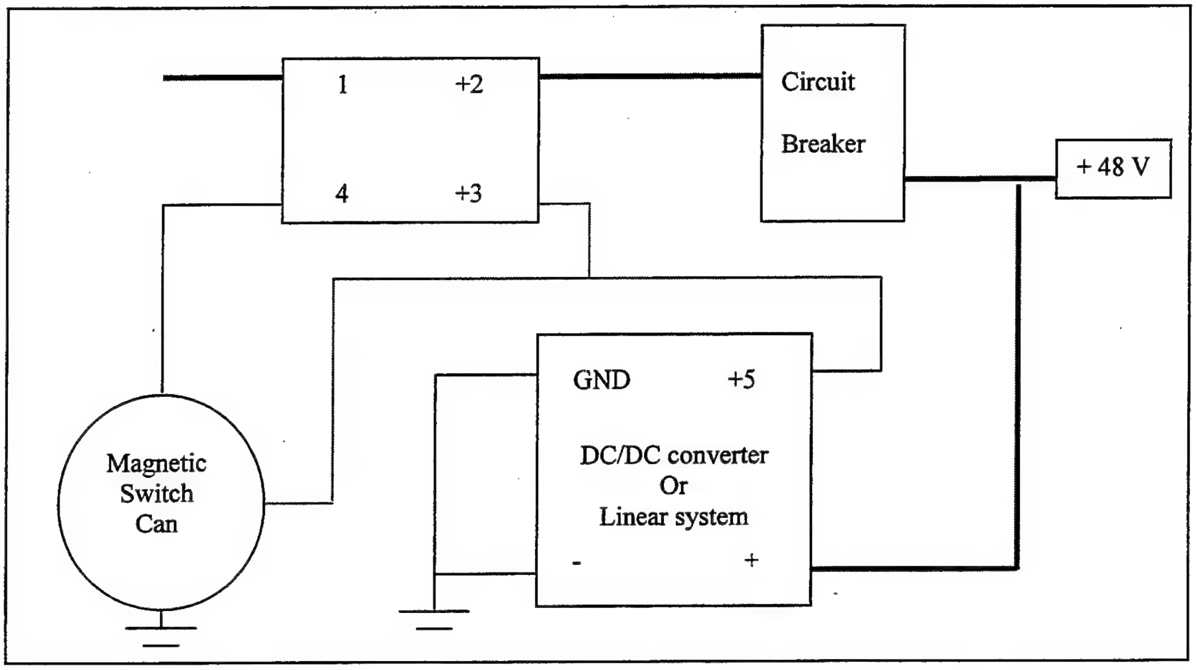


Figure IV-6: Main scheme (main power relay + magnetic switch)

The electronic scheme of the magnetic switch system is available in appendix C.

The test of the both systems gives reason to the DC/DC converter. The load current (140 mA) was too big for the linear circuit that become very hot. To solve this problem a resistor that dissipates heat was put just before the linear circuit. The linear circuit stayed cool but the resistor became too hot. So the main power relays were finally built with a DC/DC converter (See picture on next page).

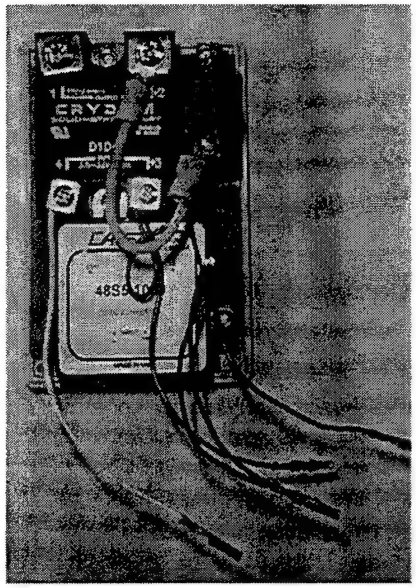


Figure IV-7: Final solution that will be use for the main power relay.

b. Main Power Bus

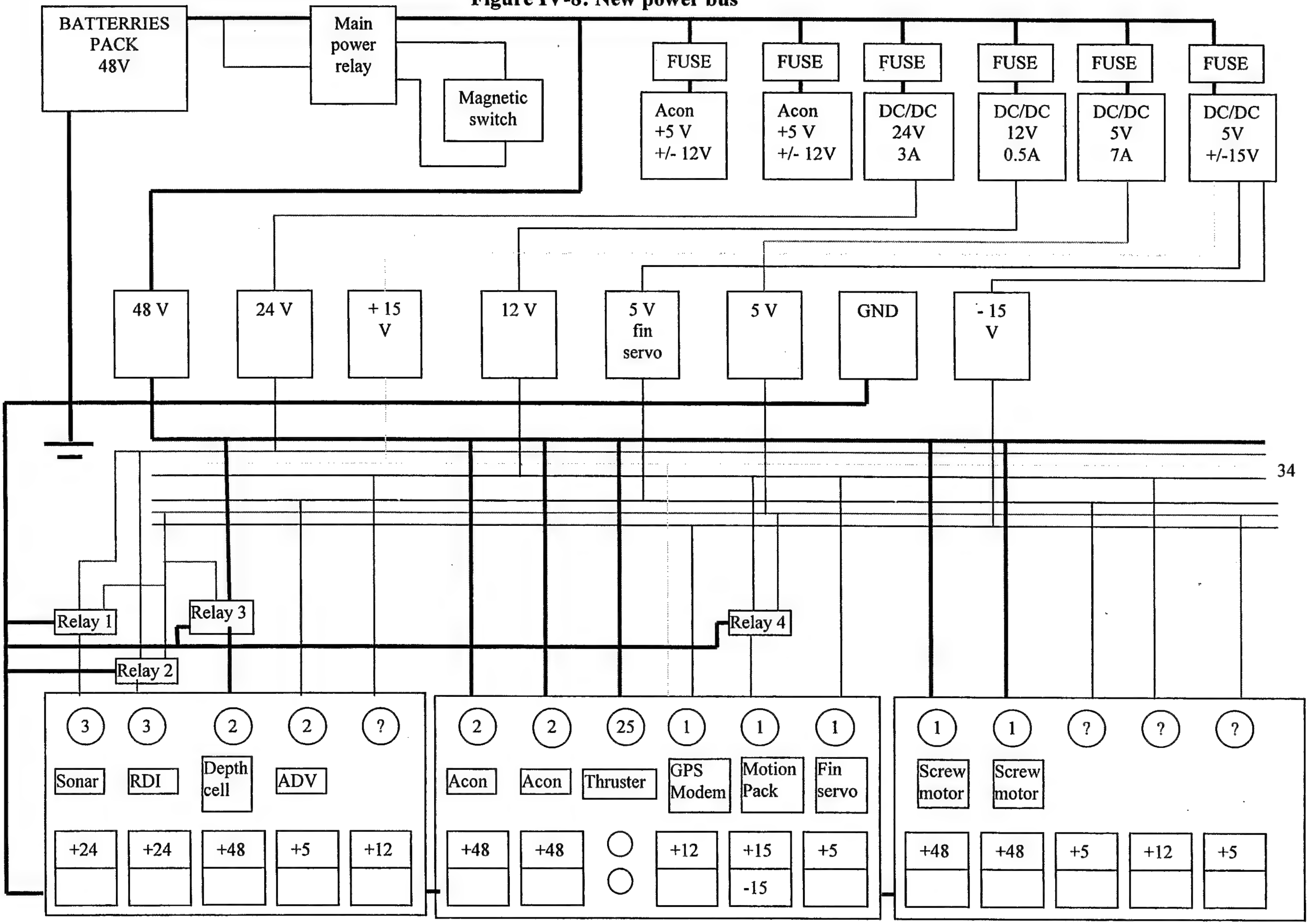
The next step was to adapt the component to the new 48 V power. The problem with a 48 V power is that it is use with electronics component that are not designed for so much power. The bigger voltage you can use is currently 12 V.

So, the component could be put together when they use the same voltage (+ 48 V, + 24 V,etc…). But after some discussion with the staff, a decision to separate some components using the same power was taken because of the electronics noise. For example, control surface servos makes a lot of noise so, we will use a separate DC/DC converter for them.

When the final list of component was closed, DC/DC converter will be search with the good current and voltage. This step was difficult because of the specificity of the need (48 V to 5V, 48V to 12V,etc…).

The entire components that will compose the new bus were ordered. These components are: DC/DC converters, circuits breakers, Acon power suppliers for computers, Solid state relay, components for the main power relay (linear circuit…).

Figure IV-8: New power bus



D. SUMMARY

This chapter provides a description of the component choices for the power bus and the design of it. It also provides schemes of the main power relay and of the entire wiring of the power bus.

V. SCREW MOTOR MODELING

A. INTRODUCTION

The *Phoenix* currently used 24 V. In the new boat, the new voltage permits to increase the range of the AUV. To know with accuracy the range, a model and simulation of the electric consumption is performed. This screw motor model is the first step of a work that can be continue on future work to obtain a model of the entire boat. The first section describes the brushless motor. The second section presents the model and simulation results.

B. BRUSHLESS MOTOR

Brushless motors convert electrical energy into mechanical energy through the interaction of two magnetic fields. A permanent magnet assembly produces one field, the other field is produced by an electrical current flowing. This two field result in a torque which tends to rotate the rotor. As the motor turns, the current in the windings is commutated to produce a continuous torque output. In fact, the brushless motor seems like a brush motor inside out. In today's typical brush motor, the magnets are mounted on the motor case (the stator) with the windings on the shaft (the armature). As the armature spins, "brushes" rub against a commutator on the armature to switch electricity on and off in the windings. This switching causes a reversal in the polarity of the windings that reacts against the permanent magnets and causes the motor to spin (Moving coil design).
In the brushless motor, a shaft with a permanent magnet is mounted on two ball bearing and the windings are fixed to the case. Power transistors on the controller (Servo amplifier) electronically switch each winding. Hall effect sensors detect the position of the permanent magnet in relation to the windings, and tell the speed controller which winding to turn on. This design is called a moving magnet design.

The advantages of this motor are numerous:

- There is less radio noise generated to interfere with the remote control. In our application, it's very important because of the big part take by the computer and the electronics: less you have electronic noise, better are command and signal transmissions operations in the boat.
- When a brush motor spins fast, the brushes will tend to "fly" over the commutator causing arcing and heating. This phenomenon doesn't exist in brushless DC motor.
- More efficiency (better torque) than brushes motors

C. MODELING

1. Model

The electric part in a DC brushless motor is represented by Figure V.1:

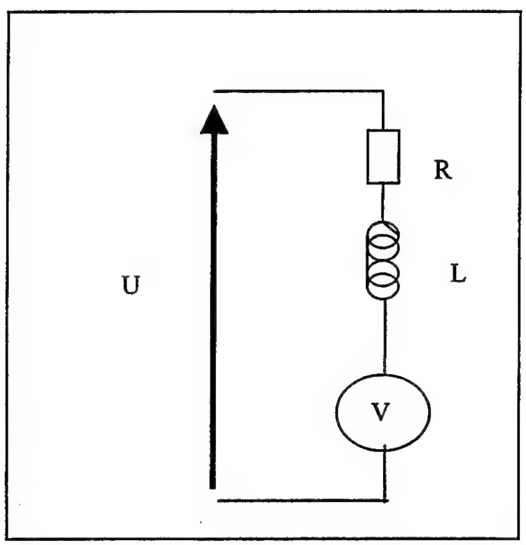


Figure V-1: Electric part of the brushless motor

A simple circuit analysis of Figure V-1 yields the following basic motor equation:

$$U(t) = i(t)\,R + V + L\,(di(t) / dt) \qquad \text{V.1}$$

With U(t): applied voltage (volts)

i(t): motor current (Amps)

L: winding inductance (Henry)

Rt: resistance (Ohms)

V: back EMF voltage (Volts)

So, with the Laplace operator, we obtain:

$U(p) = R\, i(p) + V(p) + L\, p\, i(p)$

$U(p) - V(p) = i(p)\,(R + L\, p)$

$$\mathbf{i(p) = U(p) - V(p) / (R + L\,p) \quad V.2}$$

So we obtain the scheme:

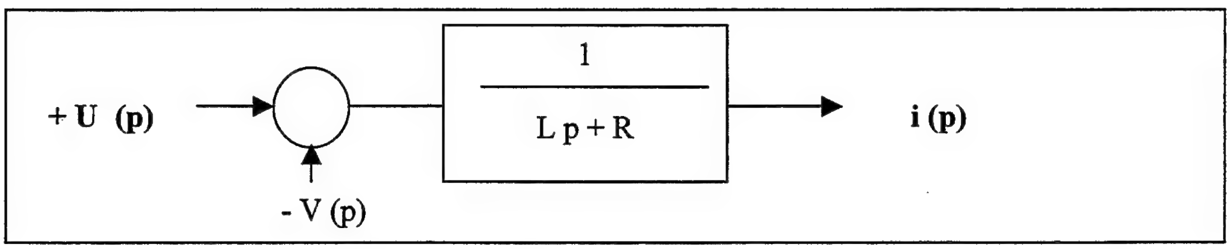


Figure V-2: Electric part scheme

This model is the model for the electric part but now, we must take account of the dynamic part (the mechanical part).

The torque output of the motor is function to the current in the winding and the load torque.

$$\mathbf{T = K_t\, i - T_l \quad V.3}$$

Where T is the total torque output of the motor (Dynamic torque en N.m)

$K_t\, i$ = drive torque and T_l = Load torque

The dynamic equation are based on Newton law F = m a. This is rewritten in rotational form and with a term to account for viscous damping.

$$\mathbf{T = J\,\alpha + D\,\omega = K_t\, i - T_l \qquad V.4}$$

Where T: Dynamic torque (N.m)

α: Angular acceleration (rad/sec^2)

ω: Angular speed (rad/sec)

D: Viscous damping constant (N.m/rad/s)

J: Moment of inertia (Kg.m^2)

Kt: Torque constant (N.m/A)

Note that T is the Dynamic torque. Any steady state torque produced by the motor is ignored, since it does not influence dynamic performance. Note also that there are two components of dynamic torque. One component accelerates the motor ($J\alpha$) and the other overcomes damping ($D\omega$).Rewriting the preceding equation using Laplace notation, we have (p = Laplace operator)

$$T = J\,p\,\omega + D\,\omega \qquad \text{V.5}$$

So the transfer function which are

$$\boxed{\omega\,(p) = [\,K_t / (\,J\,p + D)\,]\,I\,(p) - [\,T_l\,(p) / (J\,p + D)]} \qquad \text{V.6}$$

where ω: Speed (rad/sec)

I: Current

K_t: Torque constant (N.m/A)

J: Inertia (Kg.m^2)

p: Laplace operator

D: Viscous damping constant (N.m/rad/s)

The scheme for the mechanical part is:

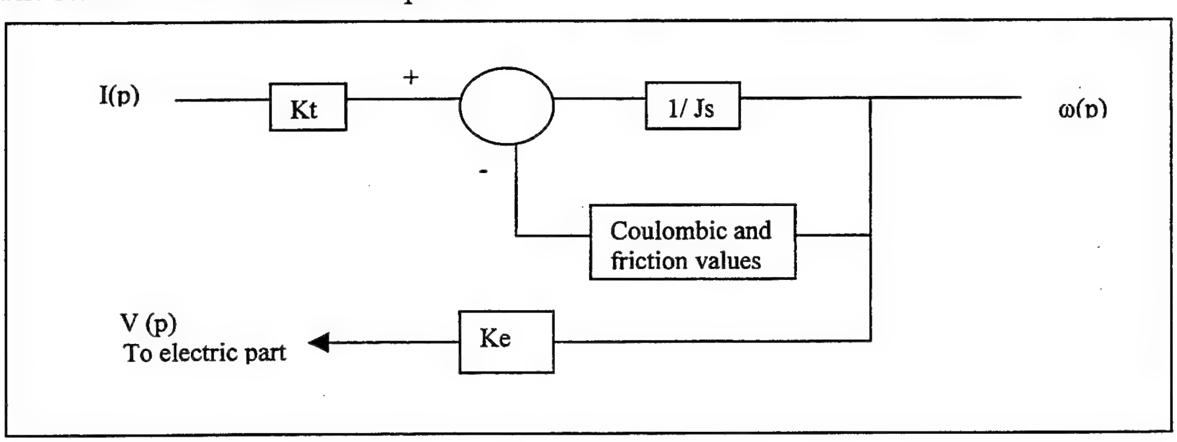


Figure V-3: Mechanical part of the brushless motor

2. Simulink Modelisation:

a. Simulink presentation:

Simulink is an extension to Matlab that permits rapidly and accurately build computers models of dynamical systems using block diagrams notations. Thus, you can modelise complex non-linear models. The strong point of this software is that it provides a graphical user interface (GUI) for building models as block diagrams using a library of sinks, source, linear and non linear components and connectors. It's also possible to customize and create yours own blocks.

Models are hierarchical, and can be built using both top down and bottom up approaches. The system can be viewed at a high level, then, a double click on blocks to go down through the levels to see increasing levels of models details. This approach provides insight into how a model is organized and how its parts interact.

C code can be generated with Simulink tools. These tools are *Real Time workshop* associated with *stateflow.* This advantage of this code is that you can use it on numerous computer platforms. This code was not generated, as the *stateflow* was not available on the Simulink version of the NPS.

b. Model of the motor:

- Without load torque:

The model built simulates the motor currently uses in the new boat. The first model is a model built with no load torque.

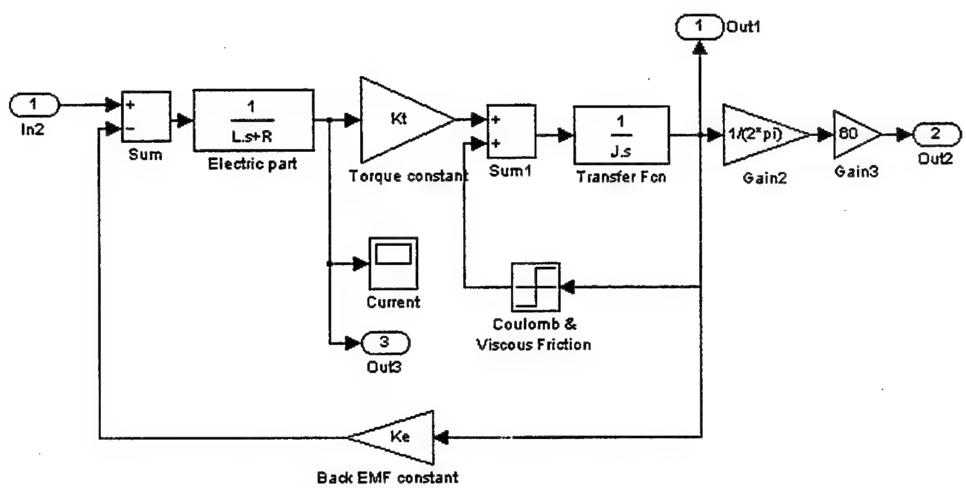


Figure V-4: Model of the motor without load torque

This model is a subsystem of the total system which permits to scope the speed (rad/s, rpm), current, etc. This second model also permits to enter the values of the different parameters thanks to mask windows.

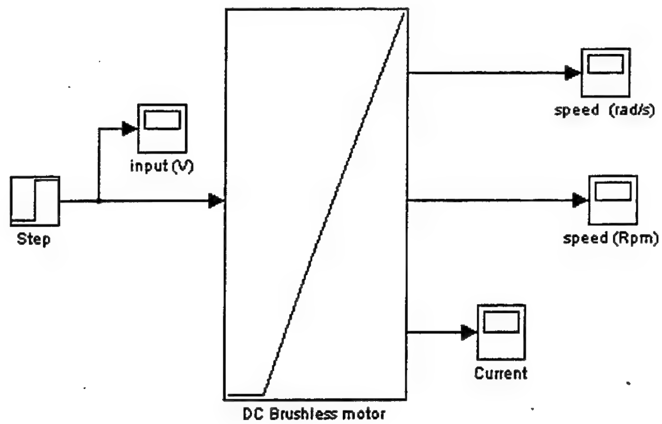


Figure V-5: Model for visualization

c. *Test:*

Tanks to the mask windows, the parameter can be adjust :

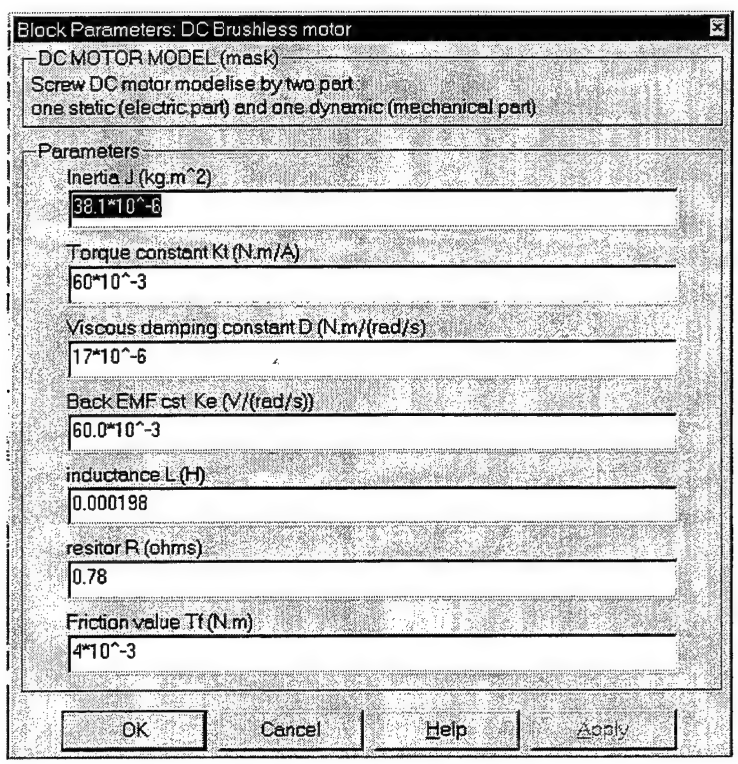


Figure V-6: Window for entering the model values [Lalaque, 1999]

A command voltage (reference voltage) can be entering as input of all the system. With a reference voltage of 17 V, the simulated results obtained are:

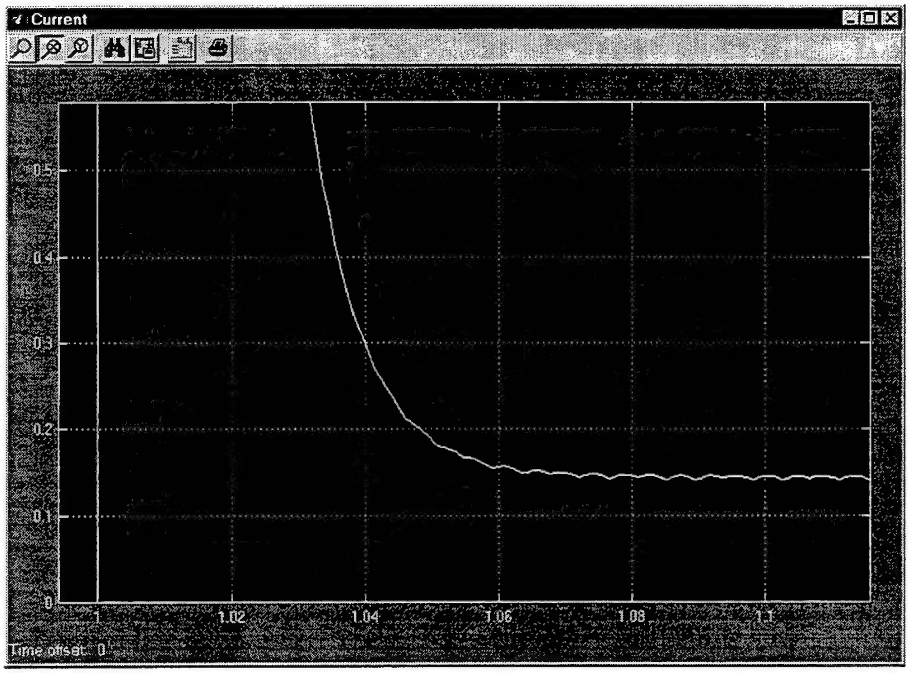


Figure V-7: Motor current (no load)

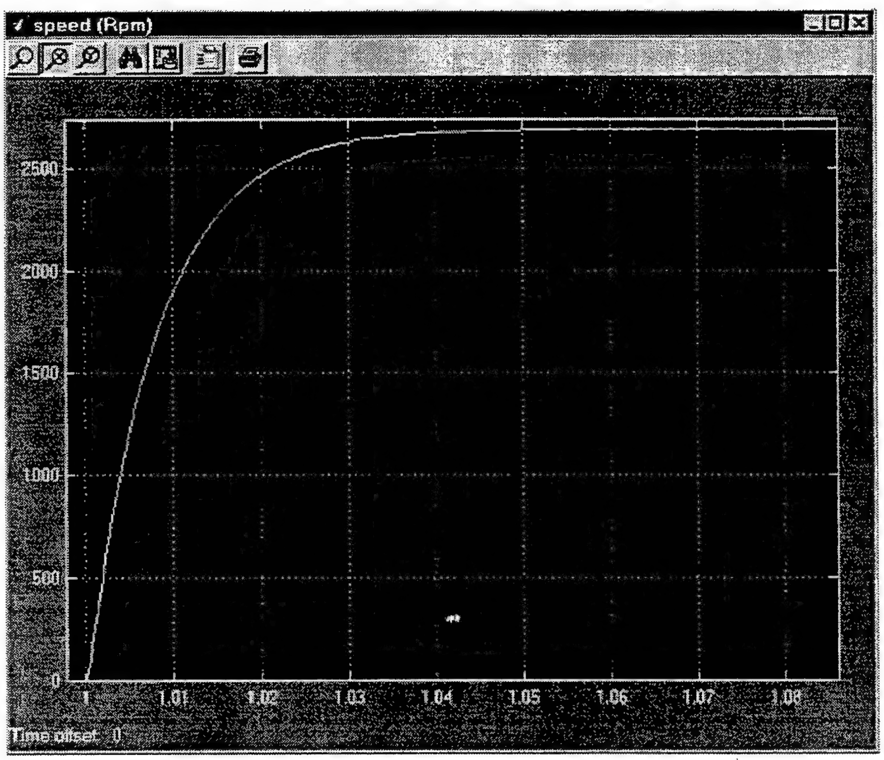


Figure V-8: Motor speed in rpm (no load)

Characteristics	Manufacturer data	Model Results	experiments
No load current (A)	0.152	0.144	0.188
Peak current (A)	21.8	20	No results
No load speed (rpm)	2652	2687	3000

The peak current is around 20 amps (data: 21.8) and the no load current is round 0.144 (data: 0.152). The results between the test, the model, and the characteristic given by the constructor are very close. This confirms the accuracy of the Simulink model. The no load speed is also very close between the Simulink model, the test and the manufacturer characteristics. So, as the accuracy of this model is demonstrated, we can work on the speed to simplify the system.

The model can be simplify as:

$$U/\omega = K / (1 + \tau p)$$

With K = gain in rad/s/V and τ the time constant.

The parameter were read on the speed curve:

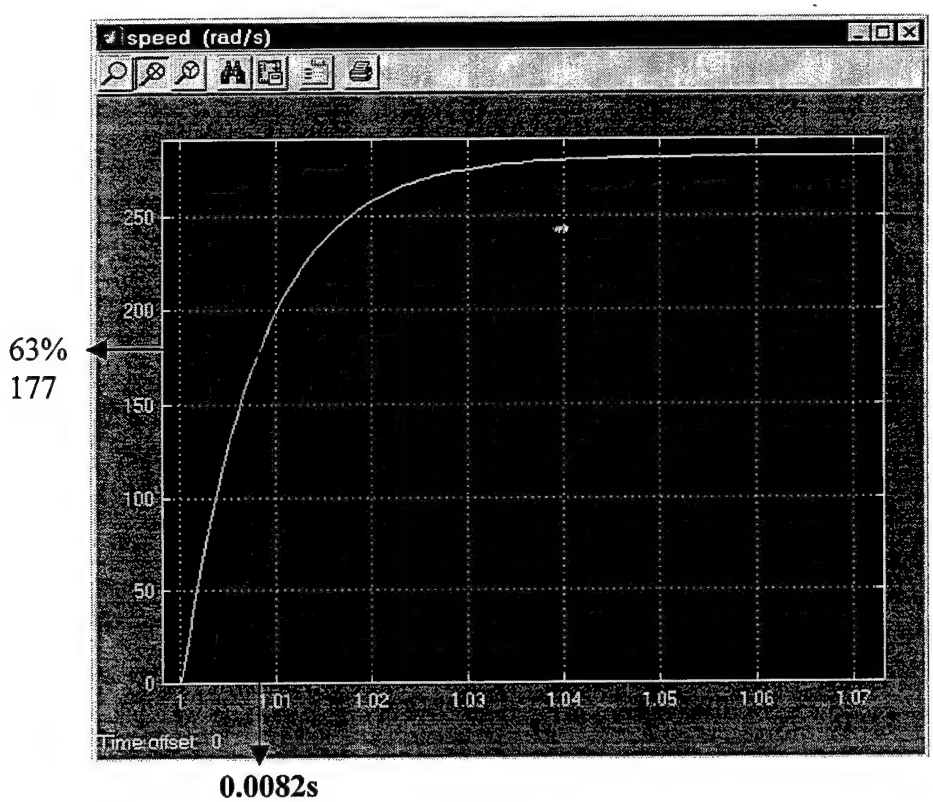


Figure V-9: Motor speed in rad/s

The result are K =(281/17)=16.52 and $\tau = 8 * 10^{-3}$

So, the simple model is:

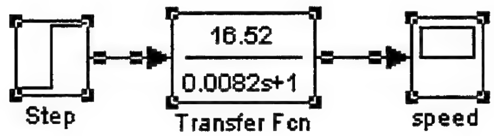


Figure V-10: Simplification of the no-load model

This simple model gives the same results than the first model.

➤ With load torque:

To determine the load torque, some test must be done on the propeller. These test being expensive, they were not done but the following paragraph gives the way to follow.

The first assumptions is that

$$\mathbf{T_{load} = Q\ f\ (\omega)} \quad \mathbf{V.7}$$

With T_{load} = Load torque (Torque of the water) in N.m

f (ω) = Function of ω ($|\omega| * \omega$) with ω in rps (put in a Matlab function)

Q = Coefficient find by test on propeller (non dimension)

$$\mathbf{T_{load} = Q * |\omega| * \omega} \quad \mathbf{V.8}$$

Now if we have found the coefficient find by test, the system below can be built:

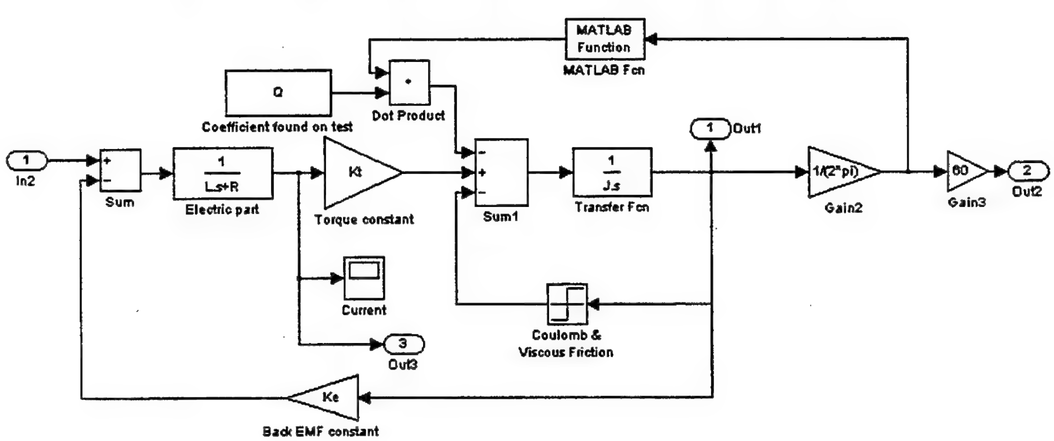


Figure V-11: Model with load torque

D. SUMMARY

Many applications can be found for this model. The first is that model permits (if the load torque is known) to calculate the consumption of the motor at every moment. This is essential to calculate the power consumption of the boat.

In the model, the consumption (Amps) cannot be known. This consumption changes in very short time (changing of the rotation speed and side), it's why, it's impossible to compute the consumption in hours because the peaks of current are in millisecond which is impossible to compute with a simulation in hours.

However, some work are done in this in some institute, this related work concerns hybrid vehicle and include, of course, theirs consumption. Maybe some information can be found for the future work on models of the new boat.

VI. AUV CONSTRUCTION SCHEDULE

A. INTRODUCTION

With the new boat construction, a real organization of the task is required. In fact, the new boat is not a reproduction of the *Phoenix*. So, its construction must be scheduled like a real industrial project. In fact, in the industry, all the project's task project are planned with accuracy to obtain the more short time construction for the best price.

The NPS AUV research group is a lab which is different than in the industry. The advancement of the work is really close to the research results. But for the new AUV, a schedule is needed because of the diversity of the tasks that have the same main: put the new AUV in the water for the first test.

In this way, the new boat construction was scheduled using Microsoft Project 98.

This chapter provides, first, the presentation of Microsoft Project, and secondly, the different step of the scheduling.

B. MICROSOFT PROJECT 98

Microsoft Project 98 is a project management tool like SuperProject or other software for project plannification. This software permits to manage, schedule and track all the activities. Thus, you can stay on top of theirs progress.

In fact, you can manage resources (equipment, person...), costs by knowing the resources work level (to resolve allocation) and the current or total cost expected. The strong point of this software is his compatibility with Internet: You can easily link web document to your project file or public yours project on Intranet or the web in HTML or GIF format. Thus, you can share all the information with your team.

This software, where the presentation looks like the other Microsoft product, is really user-friendly. Almost of the Microsoft products are used in a company (Word, Excel...). Thus, Microsoft Project is simple to learn because of its similarity with other product currently used.

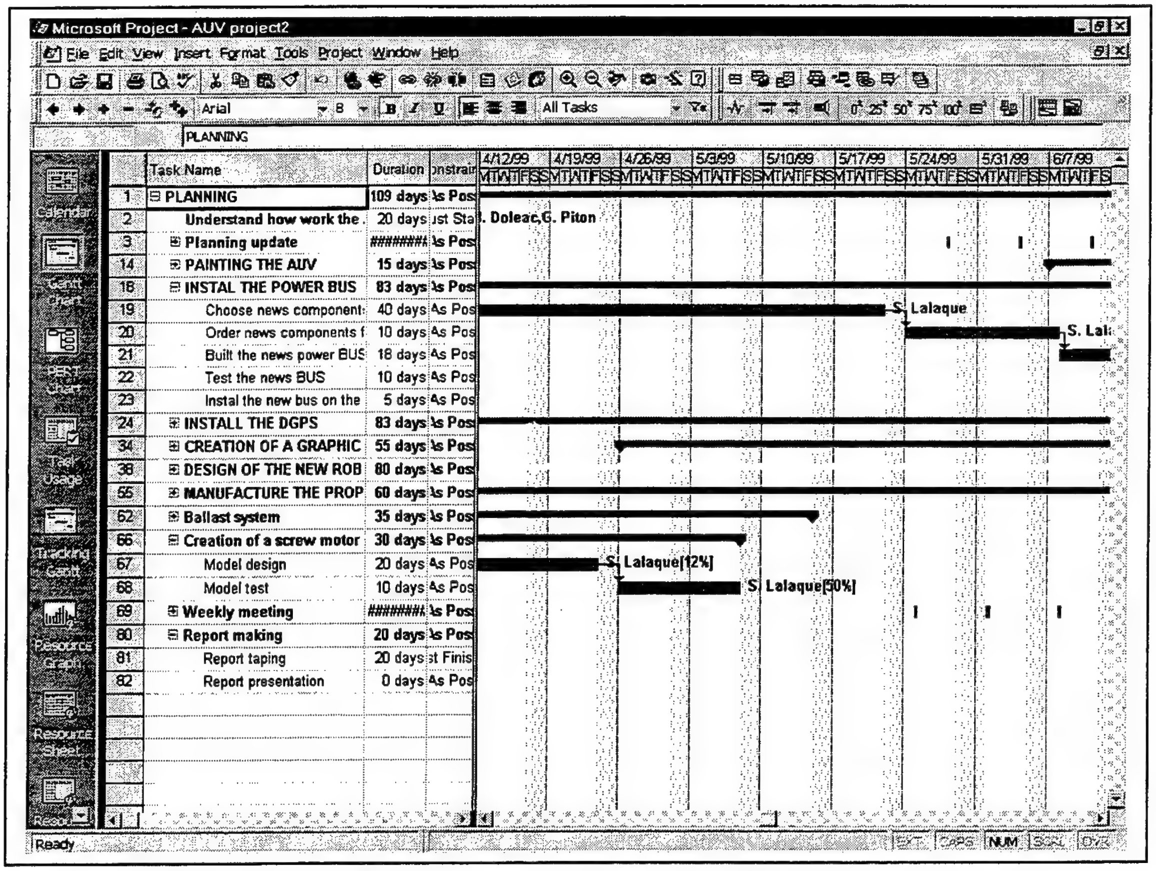


Figure VI-1: Microsoft Project 98 main windows (Gantt chart view),

The bad point in this software is the lack of accuracy. In fact, no difference is done if the resources are a person or a machine. So, it's not so good for a manufacturer. Cost of the people works are not calculated like the cost of a machine. This lack of accuracy prevents the use of this software for the big project of the manufactory. But for this application it is pretty efficient.

C. CONSTRUCTION SCHEDULE

To plan with efficiency the project, a precise map must be define to know all the step of the construction:

Define the project and the main goal:

Here, the final goal is to have a robot able to work alone. But his goal is for a very long term (6 months to 1 year). The first goal is to test the robot waterproof, the running of the motor and the DGPS system. So, as the goal is define, each member of the team propose his plan to reach this goal. Theses plans includes the task with theirs links, duration, the resource

The first plan prepared contains the mains task in which are put under-tasks. These tasks are order by resources. They are link together following the priority, the date to respect… In each task, information like duration, resources, constraints are put.

	Task Name	Duration	Constraint Type	Constraint Date
1	⊟ **PLANNING**	**109 days**	**As Late As Possible**	**NA**
2	**Understand how work the AUV**	20 days	Must Start On	Mon 3/1/99
3	⊞ **Planning update**	**44.08 days**	**As Late As Possible**	**NA**
14	⊞ **PAINTING THE AUV**	**15 days**	**As Late As Possible**	**NA**
18	⊟ **INSTAL THE POWER BUS**	**77 days**	**As Late As Possible**	**NA**
19	Choose news components for the power BUS	40 days	As Soon As Possible	NA
20	Order news components for the power BUS	10 days	As Soon As Possible	NA
21	Built the news power BUS	12 days	As Soon As Possible	NA
22	Test the news BUS	10 days	As Soon As Possible	NA
23	Instal the new bus on the AUV	5 days	As Soon As Possible	NA
24	⊞ **INSTALL THE DGPS**	**83 days**	**As Late As Possible**	**NA**
34	⊞ **CREATION OF A GRAPHIC INTERFACE**	**55 days**	**As Late As Possible**	**NA**
38	⊞ **DESIGN OF THE NEW ROBOT**	**80 days**	**As Late As Possible**	**NA**
55	⊞ **MANUFACTURE THE PROPELLER**	**60 days**	**As Late As Possible**	**NA**
62	⊞ **Ballast system**	**35 days**	**As Late As Possible**	**NA**
66	⊟ **Creation of a screw motor model**	**30 days**	**As Late As Possible**	**NA**
67	Model design	20 days	As Soon As Possible	NA
68	Model test	10 days	As Soon As Possible	NA
69	⊞ **Weekly meeting**	**44.13 days**	**As Late As Possible**	**NA**
80	⊟ **Report making**	**20 days**	**As Late As Possible**	**NA**
81	Report taping	20 days	Must Finish On	Fri 7/30/99
82	Report presentation	0 days	As Late As Possible	NA

Figure VI-2: Task name and information.

These information give to the computer, that gives many visualization possible:

- Gantt chart that displays basic task information in columns and a bar graph. The Gantt Chart makes it easy to see the schedule for tasks, the initial plan is build with this view.

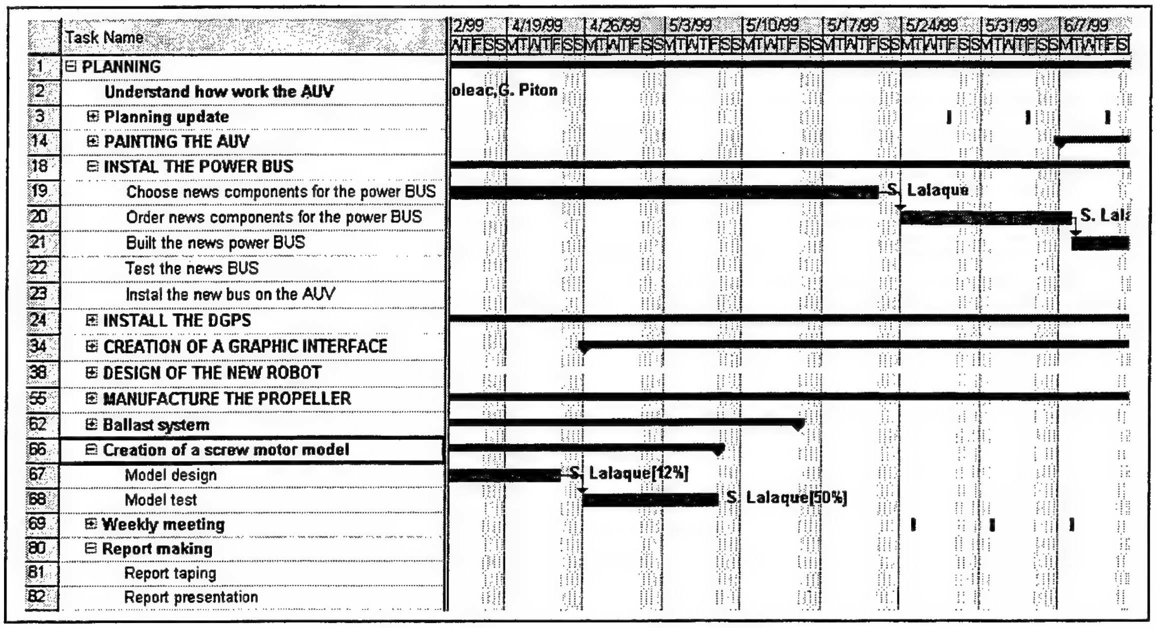


Figure VI-3: Gantt chart view.

- Pert chart view that displays tasks and task dependencies as a network diagram or flowchart. A box (sometimes called a node) represents each task and a line connecting two boxes represents the dependency between the two tasks. By default, the PERT Chart view displays one diagonal line through a task that is in progress and crossed diagonal lines through a completed task.

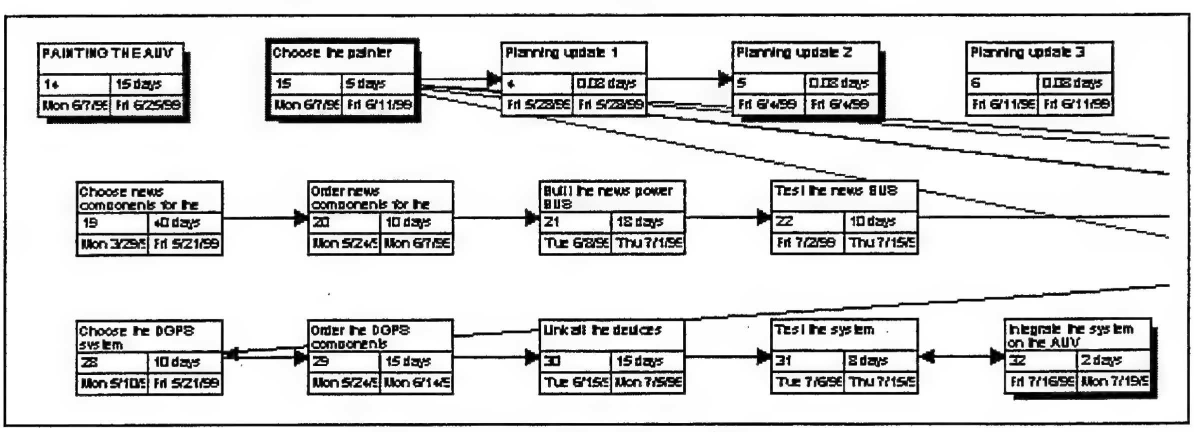


Figure VI-4: Pert chart view.

➢ Resource Graph view graphically displays information about the allocation, work, or cost of resources over time. It permits to review the resource information for one resource at a time, for selected resources, or for a resource and the selected resources simultaneously, one for the individual resource and one for the selected resources, so you can compare them.

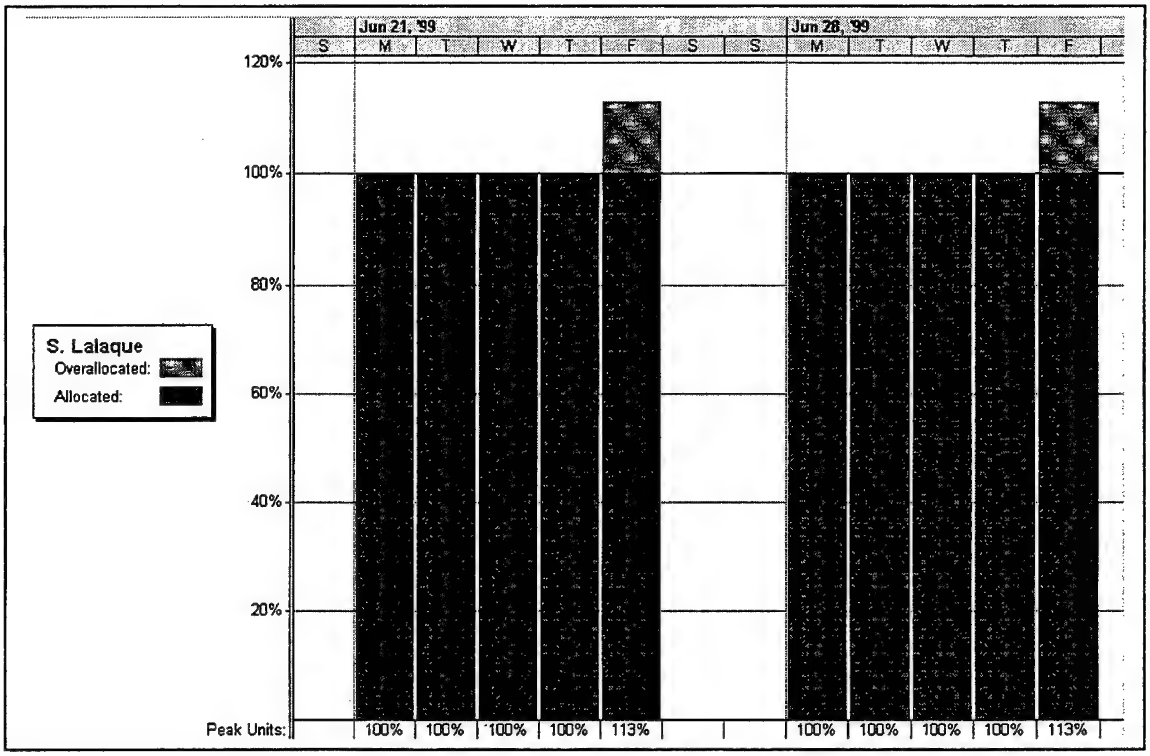


Figure VI-5: Resource view.

Finally, after the making of the plan, you can redefine, adjust to be the more efficient in the track of you goal. And after, every week, a tracking and managing work of the plan is done to tune close to the reality. That permits to know is the end date can be keep and redefine, every week the priority.

D. SUMMARY

For our case, the Gantt chart is the best view because of the rapid visualization of the end of the project. The resources view is not so useful for the research project because, often, the resources are not limited.

In conclusion, this plan must be maintain by a person in charge of the AUV project scedulinbg by an update after each meeting.

VII. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

The main project, the new AUV construction, is not a simple transfer of the *Phoenix* technologies into the new shape. This construction is a total adaptation of old components (Sonars, ADV, RDI...), new components (GPS, Thrusters, motors, etc...) and the new power capacity (48V). So, the power bus needed to be designed entirely to prepare the boat to be the support of research of the AUV department.

In fact, the voltage increase for the new boat led to a lot of "adaptation work". This work was necessary to obtain that the new boat runs without problem and in total security. The design of the new boat power bus will permit to have easy change of the component in it. It is very important when you know that a lot of tests are done on it. But it was difficult to adapt the component together. In fact, 48 V is not a present voltage in the "electronic world" where 24 V or 12 V are currently use. But a lot of research, discussions with specialist, permits to bypass the problem. Moreover, it permits to begin on good base because, after a lot of year of adaptation, changing on the *Phoenix*, many information were lost that gives modifications difficult to be done.

In an another way, the Simulink modelization permits to modelize screws motors as the first step of the electric model of the new boat.

Lastly, the scheduling on Microsoft Project 98 permits to managing and tracking the construction with accuracy to be more efficient in the priority of the work.

B. RECOMMENDATIONS

The most important goal to achieve now is to put the entire components in the new boat to test it in the water. Moreover, all the changing of configuration must be written to always have information available for the person who will work on the new boat. The other work is to continue the construction of electric models of the different component to obtain a consumption of the entire boat and thus, forecast the time of the missions. But , for that, it would be most productive to find a student involved as much as possible in electronic science engineering.

APPENDIX A

Wiring list

List of component

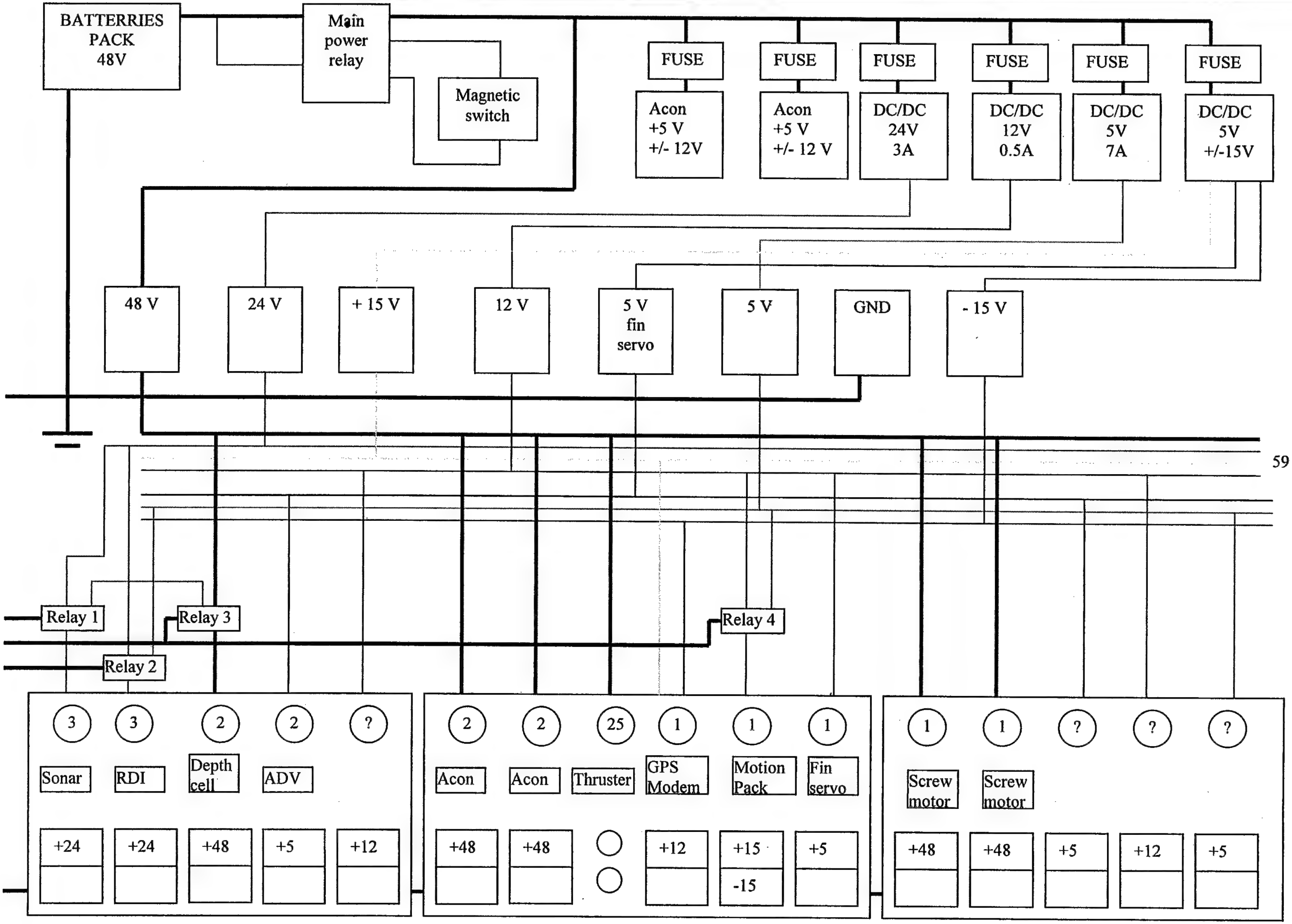
COMPONENT	PART	SUPPLIER	PRICE	QTY	TOTAL
DC/DC converter 48 to 5 (8A)	48S5.5000XW	Calex	176.4	1	176.4
Mounting kit for 48 to 5	MS9	Calex	36.75	1	36.75
DC/DC converter 48 to 5 & 15 (5A)	48T5.15SW	Calex	143.85	1	143.85
Mounting kit for 48 to 5 & 15	MS9	Calex	36.75	1	36.75
DC/DC converter 48 to 24 (3A)	48S24.3HE	Calex	113	1	113
no mounting kit					0
DC/DC converter 48 to 12 (500mA)	48S12.500EC	Calex	78.75	1	78.75
Mounting kit for 48 to 12	MS6	Calex	25.2	1	25.2
DC/DC converter 48 to 5 (1A)	48S5.1000	Calex	120.75	1	120.75
Mounting kit for 48 to 5	MS6	Calex	25.2	1	25.2
Acon Power supplier	RT100T4805-12	ACON, Inc		2	0
Servo amplifier	BE30A8	a.m.c	439	2	878
Relay gordos ODC5	793 7140	Allied	8.67	10	86.7
Circuit Breaker 10A (W23...)	44F943	Newark	19.08	3	57.24
Circuit Breaker 15A (W23...)	44F944	Newark	19.08	3	57.24
Circuit Breaker 20A (W23...)	44F945	Newark	19.08	2	38.16
Circuit Breaker 25A (W23...)	44F946	Newark	19.08	1	19.08
Circuit Breaker 1A (W58-XB...)	PB242-ND	Digikey	13.08	2	26.16
Circuit Breaker 2A (W58-XB...)	PB243-ND	Digikey	13.08	2	26.16
Circuit Breaker 3A (W58-XB...)	PB244-ND	Digikey	13.08	3	39.24
Circuit breaker 5 A (W58-XB...)	PB245-ND	Digikey	9.85	2	19.7
Circuit breaker 7 A (W58-XB...)	PB246-ND	Digikey	9.85	3	29.55
Circuit breaker 4 A (W58XC...)	PB196-ND	Digikey	7.56	2	15.12
Circuit breaker 6 A (W58XC...)	PB198-ND	Digikey	4.84	6	29.04
Circuit breaker 8A (W58XC...)	PB200-ND	Digikey	4.84	2	9.68
Magnetic switch					0
microcontroller					0
Plastic enclosures	HM164-ND	Digikey	13.36	4	53.44
DIN RAIL 7.5mm				2 meter	
Communication wire and cable dust	617-1111		135.3	1	135.3
Feed through terminal block				7	0
TOTAL					**1519.81**

Range Calculation

	Consumption	Range (hours)
Load current		
2 PC104	20.00	
Sonar	15.00	
Main power relay	5.00	
Electronic power	2.00	
RDI	8.00	
ADV	5.00	
Motion pack	7.00	
Depht cell	0.23	
Hall sensor	7.00	
TOTAL	67.23	24h 58
Extreme case		
All components	704.83	2h 22
Medium case		
Load current	67.23	
Screw motor	300.00	
TOTAL	367.23	4h 35
With fin servo		
Medium case	367.23	
Fin servo	30	
TOTAL	397.23	4 h 14

Consumption

COMPONENTS	Power supplier	Ouput			
		voltage	Current (mA)		Cmption
		(V DC)	MAX	typical	(W)
PC 104 (design acquisition,exe)	*ACON*	5		2000.00	10
	RT100T4805-12	+/- 12			
PC 104 (stategic level)	*ACON*	5		2000.00	10
	RT100T4805-12	24			
Screw motor / Servo amp (2)		48		6500.00	300.00
GM5143D005 / BE30A8					
Thruster (x4)	(current :6 x 4)	48		24000.00	300
Main power relay	48S5.1000	5		1000.00	5.00
RDI		48		170.00	8.00
ST1000	48S24.3HE	24	900	300.00	7.50
ST725		24	900	300.00	7.50
ADV		24		210.00	5
Depth cell (output 0-10 V)	48T5.15SW	15		15.00	0.23
Motion Pack		+-15		252.00	7.00
Freewave modem DGR 115	48S12.500	12	< 600	180.00	1.00
Electronic power for thruster		12			2.00
GPS		12		200.00	1.80
Control surface servo (x 6)	48S5.5000XW	6		5000.00	30.00
Power for hall sensors		6		30.00	7.00
Acoustic modem					
Camera trictech					
Pump (x2)		12		15000.00	180.00
TOTAL of load current and Watt				11657.00	67.23
TOTAL of variable ct and Watt				45500.00	632.80
TOTAL of current and Watt				57157.00	704.83



BATTERRIES PACK 48V
Main power relay
Magnetic switch
FUSE
FUSE
FUSE
FUSE
FUSE
FUSE
Acon +5 V +/- 12V
Acon +5 V +/- 12 V
DC/DC 24V 3A
DC/DC 12V 0.5A
DC/DC 5V 7A
DC/DC 5V +/-15V
48 V
24 V
+ 15 V
12 V
5 V fin servo
5 V
GND
- 15 V
59
Relay 1
Relay 3
Relay 2
Relay 4
3
3
2
2
?
Sonar
RDI
Depth cell
ADV
+24
+24
+48
+5
+12
2
2
25
1
1
1
Acon
Acon
Thruster
GPS Modem
Motion Pack
Fin servo
+48
+48
+12
+15
-15
+5
1
1
?
?
?
Screw motor
Screw motor
+48
+48
+5
+12
+5

APPENDIX B

Components data sheet

6 Watt Single Series DC/DC Converters

Features

- Low Profile Copper Case (0.375" High)
- Six-Sided Shielded Case
- Low Input/Output Noise Operation
- 500 VDC Minimum Input to Output Isolation
- Output Overvoltage Clamp
- Fixed Frequency Operation Independent of Line and Load
- Highly Regulated/Low Drift Output
- Rugged High Speed MOSFET Power Chopper
- 5 Year Warranty

Description

These 6 Watt Single Output DC/DC converters are suitable for telecommunications and industrial control applications that call for direct PCB mounting.

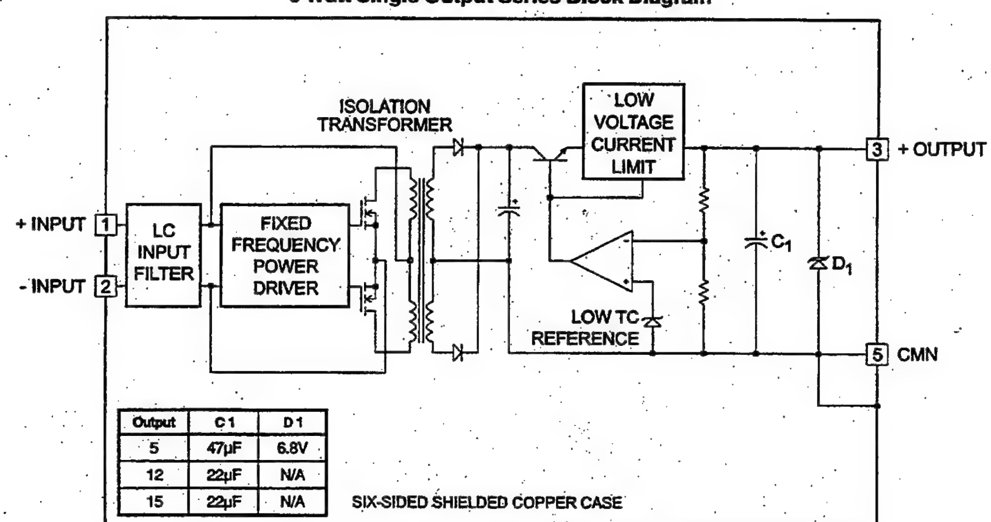
The converters in this series are designed with an LC input filter, a MOSFET push-pull power chopper, and an isolation transformer. A linear post regulator provides excellent line and load regulation.

Noise is reduced by housing each unit in a six-sided shielded copper case. The CALEX 5 Year Warranty covers all converters in this series.

Selection Chart				
Model	Input Range VDC		Output VDC	Output mA
	Min	Max		
12S5.1000 *	11.16	13.20	5.0	1000
12S12.500 *	11.16	13.20	12.0	500
12S15.400 *	11.16	13.20	15.0	400
24S5.1000 *	22.32	26.40	5.0	1000
24S12.500 *	22.32	26.40	12.0	500
24S15.400 *	22.32	26.40	15.0	400
28S5.1000 *	26.04	30.80	5.0	1000
28S12.500 *	26.04	30.80	12.0	500
28S15.400 *	26.04	30.80	15.0	400
48S5.1000 *	44.64	52.80	5.0	1000
48S12.500 *	44.64	52.80	12.0	500
48S15.400 *	44.64	52.80	15.0	400

* UL Recognition: UL 1459-2

6 Watt Single Output Series Block Diagram



Output	C1	D1
5	47µF	6.8V
12	22µF	N/A
15	22µF	N/A

6 Watt Single Series DC/DC Converters

Input Parameters*

Model		12S5.1000	12S12.500	12S15.400	24S5.1000	24S12.500	24S15.400	Units
Voltage Range	MIN	11.16			22.32			VDC
	MAX	13.20			26.40			
Reflected Ripple (2), 0-20MHz bw	TYP	7			5			mA P-P
	MAX	15			10			
Input Current Full Load	TYP	700	740	720	330	370	360	mA
No Load	TYP	43	43	54	20	23	27	
Efficiency	TYP	60	68	69	63	68	69	%
Switching Frequency	TYP	55						kHz
Maximum Input Overvoltage, 100ms No Damage	MAX	15			30			VDC
Turn-on Time, 1% Output Error (3)	TYP	1						ms
Recommended Fuse		Slow Blow Type (4)						
Model		**28S5.1000**	**28S12.500**	**28S15.400**	**48S5.1000**	**48S12.500**	**48S15.400**	**Units**
Voltage Range	MIN	26.04			44.64			VDC
	MAX	30.80			52.80			
Reflected Ripple (2), 0-20MHz bw	TYP	3			10			mA P-P
	MAX	10			20			
Input Current Full Load	TYP	288	318	309	170	190	185	mA
No Load	TYP	19	19	21	16	16	17	
Efficiency	TYP	62	67	69	60	66	68	%
Switching Frequency	TYP	55						kHz
Maximum Input Overvoltage, 100ms No Damage	MAX	35			60			VDC
Turn-on Time, 1% Output Error (3)	TYP	1						ms
Recommended Fuse		Slow Blow Type (4)						

Output Parameters*

Model		12S5.1000 24S5.1000 28S5.1000 48S5.1000	12S12.500 24S12.500 28S12.500 48S12.500	12S15.400 24S15.400 28S15.400 48S15.400	Units
Output Voltage		5	12	15	VDC
Rated Load (5)	MIN	0	0	0	mA
	MAX	1000	500	400	
Voltage Range 100% Load	MIN	4.95	11.90	14.90	VDC
	TYP	5.00	12.00	15.00	
	MAX	5.05	12.10	15.10	
Load Regulation 0-100% Load	TYP	0.02			%
	MAX	0.15			
Line Regulation Vin = Min-Max VDC	TYP	0.02			%
	MAX	0.10			
Short Term Stability (6)	TYP	0.02			%
Long Term Stability	TYP	0.20			%/kHrs
Transient Response (7)	TYP	20			µs
Dynamic Response (8)	TYP	120	55	50	mV peak
Input Ripple Rejection (9)	TYP	60			dB
Noise, 0-20MHz bw (2)	TYP	10			mV P-P
	MAX	40			
Temperature Coefficient	TYP	50			ppm/°C
	MAX	200			
Overvoltage Clamp (10)	TYP	6.8	-	-	VDC
Short Circuit Protection to Common for all Outputs		Short Term, 1 Minute Maximum (4)			

NOTES

* **All parameters measured at Tc=25°C, nominal input voltage and full rated load unless otherwise noted. Refer to the CALEX Application Notes for the definition of terms, measurement circuits and other information.**

(2) Noise is measured per CALEX Application Notes.

(3) Turn-on time is defined as the time from the application of power until the output is within 1% of its final value.

(4) For long term short circuit protection of the converters, install a slow blow fuse in the input circuit. Choose a fuse size that is 125% of your applications actual input current and does not exceed 115% of the full load input current.

(5) No minimum load required.

(6) Short term stability is specified after a 30 minute warm-up at full load, and with constant line, load and ambient conditions.

6 Watt Single Series DC/DC Converters

General Specifications*			
All Models			Units
Isolation			
Isolation Voltage 10μA Leakage Input-Output	MIN	500	VDC
Input to Output Capacitance	TYP	75	pF
Environmental			
Case Operating Range No Derating	MIN MAX	-25 80	°C
Case Functional Range (11)	MIN MAX	-40 85	°C
Storage Range	MIN MAX	-55 90	°C
Thermal Impedance (12)	TYP	10	°C/Watt
General			
Unit Weight	TYP	1.7	oz
Chassis Mounting Kits		MS6, MS8, MS15	

(7) After a 100% step change of the load, the output voltage will be within 1% of the final value within the transient response time.

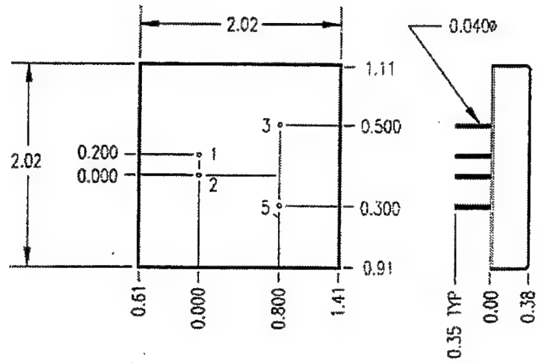
(8) Dynamic response is the peak overshoot voltage during the transient response time defined in note 7 above.

(9) The input ripple rejection is specified for DC to 120Hz ripple with a modulation amplitude of 1% Vin.

(10) For module protection only, see also Note 4.

(11) The functional temperature range is intended to give an additional data point for use in evaluating this power supply. At the low functional temperature the power supply will function with no side effects, however sustained operation at the high functional temperature will reduce expected operational life. The data sheet specifications are not guaranteed over the functional temperature range.

(12) The Case Thermal Impedance is specified as the case temperature rise over ambient per package watt dissipated.



BOTTOM VIEW SIDE VIEW

Mechanical tolerances unless otherwise noted:

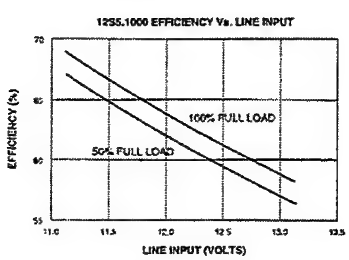
X.XX dimensions: ±0.020 inches

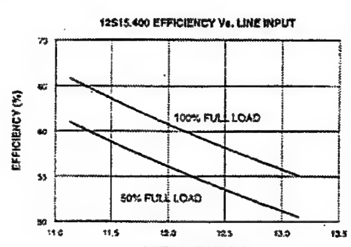
X.XXX dimensions: ±0.005 inches

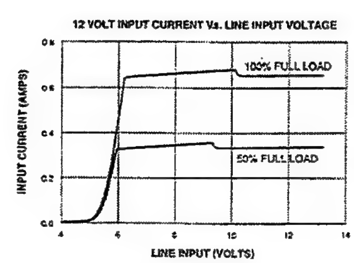
Seal around terminals is not hermetic. Do not immerse units in any liquid.

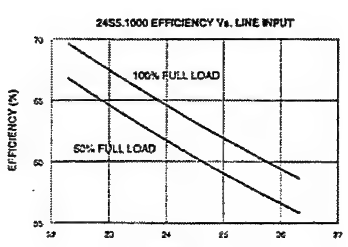
Pin	Function
1	+INPUT
2	-INPUT
3	+OUTPUT
5	CMN

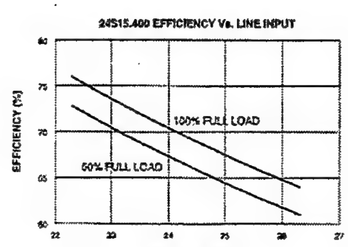
Typical Performance: (Tc = 25°C; Full Rated Load).

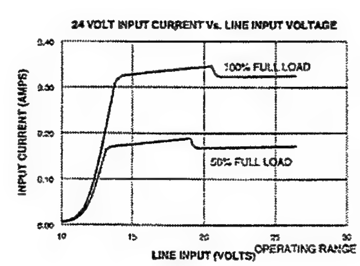






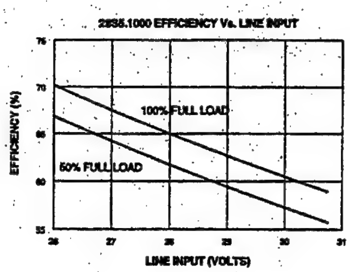


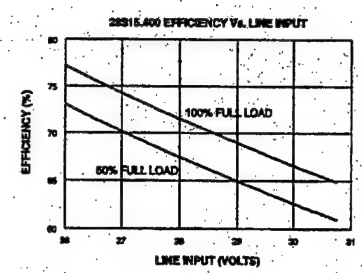


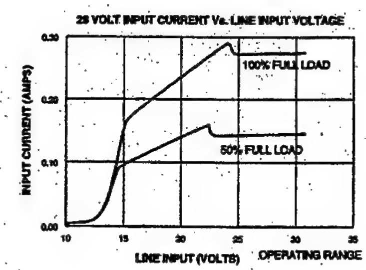


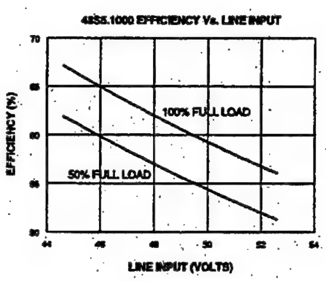
6 Watt Single Series DC/DC Converters

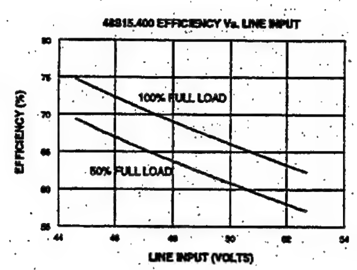
Typical Performance: (Tc = 25°C; Full Rated Load).

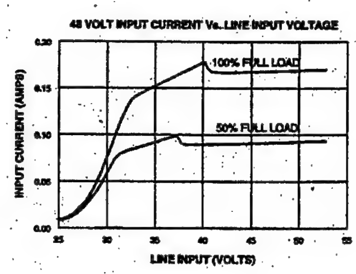


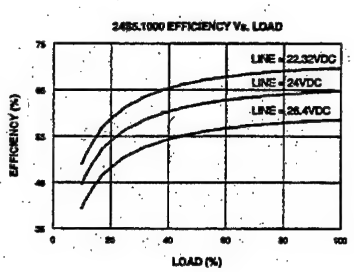


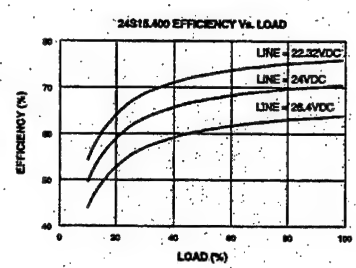


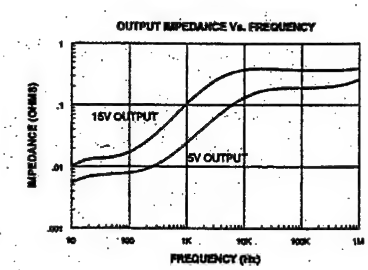












15 Watt SW Triple Series DC/DC Converters

Features

- Wide 2:1 Input Voltage Range (9-18, 18-36 or 36-72VDC)
- Low Noise, Highly Regulated Triple Outputs
- Efficiency 78% for All Line Conditions
- No Derating to 80°C Case Temperature
- Six-Sided Shielded Low Thermal Gradient Copper Case
- 500 VDC Minimum Input to Output Isolation
- Overvoltage Protected Outputs
- Pulse by Pulse Digital Current Limiting
- Five Year Warranty

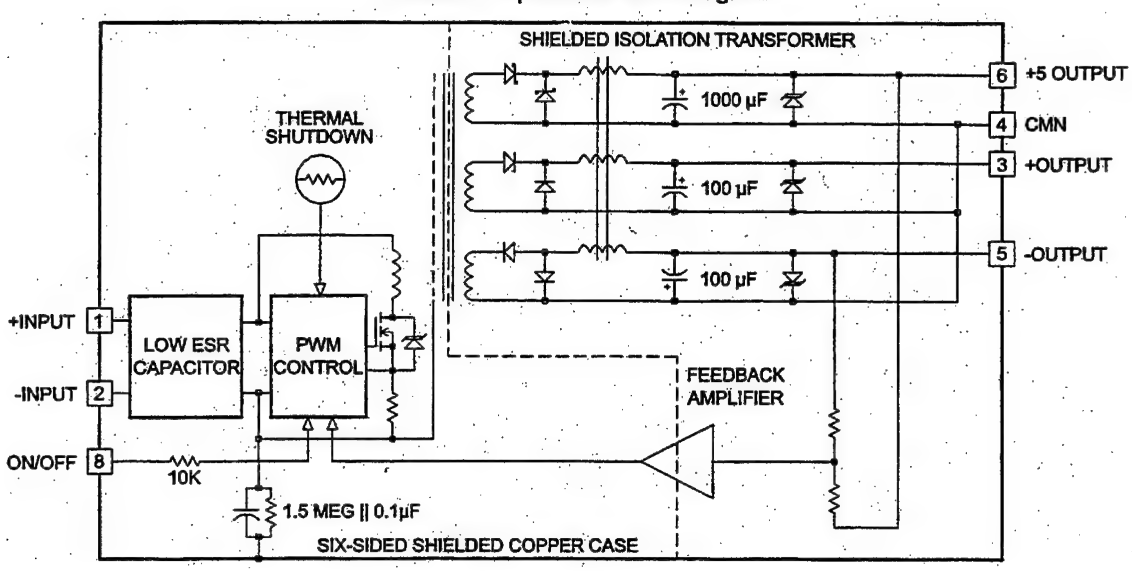
Description

These triple output converters are designed for wide input range telecommunications, medical instrument and industrial control system applications. The converters have a high accuracy feedback control circuit and coupled inductor magnetics. This combination provides linear regulator type performance with switching topology efficiency. Outstanding line and load regulation are achieved over the full input range and under the specified load current range. A logic shutdown pin is also included to inhibit converter operation as is internal thermal overload protection. The outputs and the power switch are both overvoltage protected.

Selection Chart

Model	Input Range VDC Min	Input Range VDC Max	Outputs VDC	Outputs mA
12T5.12SW	9.00	18.00	5, ±12	1500, ±310
12T5.15SW	9.00	18.00	5, ±15	1500, ±250
24T5.12SW	18.00	36.00	5, ±12	1500, ±310
24T5.15SW	18.00	36.00	5, ±15	1500, ±250
48T5.12SW	36.00	72.00	5, ±12	1500, ±310
48T5.15SW	36.00	72.00	5, ±15	1500, ±250

15 Watt SW Triple Series Block Diagram



15 Watt SW Triple Series DC/DC Converters

Input Parameters*								
Model		12T5.12SW	12T5.15SW	12T5.12SW	24T5.15SW	48T5.12SW	48T5.15SW	Units
Voltage Range	MIN MAX	9.0 18.00		18.0 36.00		36.00 72.00		VDC
Input Filter		Low ESR Capacitor						
Input Current Full Load No Load	TYP TYP	1600 25		780 18		380 16		mA
Efficiency	TYP	78						%
Switching Frequency	TYP	55						kHz
Maximum Input Overvoltage, 100ms No Damage	MAX	25		45		85		VDC
Turn-on Time, 1% Output Error	TYP	120						ms
Recommended Fuse		(2)						

Output Parameters*					
Model		12T5.12SW 12T5.15SW 24T5.12SW 24T5.15SW 48T5.12SW 48T5.15SW	12T5.12SW 24T5.12SW 48T5.12SW	12T5.15SW 24T5.15SW 48T5.15SW	Units
Output Voltage		5	±12	±15	VDC
Rated Load (3)	MIN MAX	250 1500	100 310	100 250	mA
Voltage Range 100% Load	MIN TYP MAX	4.900 5.000 5.100	11.640 12.000 12.360	14.550 15.000 15.450	VDC
Load Regulation Min-Max Load	TYP MAX	2.0 3.5	1.5 3.0	1.5 3.0	%
Line Regulation Vin = Min-Max VDC	TYP MAX	0.1 0.5			%
Short Term Stability (4)	TYP	0.02			%
Long Term Stability	TYP	0.2			%/kHrs
Transient Response (5)	TYP	50			µs
Dynamic Response (6)	TYP	85	75	70	mV peak
Input Ripple Rejection (7)	TYP	35			dB
Noise, 0-20MHz bw	TYP MAX	25 50	20 50	20 50	mV P-P
Temperature Coefficient	TYP MAX	120 250			ppm/°C
Overvoltage Clamp (8)	TYP	6.8	15.0	18.0	VDC
Short Circuit Protection to Common for all Outputs		Continuous, 8 Hours Minimum Current Limit and Thermal Overload			

NOTES

* **All parameters measured at Tc = 25°C, nominal input voltage and full rated load unless otherwise noted. Refer to the CALEX Application Notes for the definition of terms, measurement circuits and other information.**

(2) Determine the correct fuse size by calculating the maximum DC current drain at low line input, maximum load then adding 20 to 25 percent. Slow blow type recommended.

(3) The module will not be damaged if run at less than minimum load. Regulation can degrade with less than minimum load or substantial load imbalance.

(4) Short term stability is specified after a 30 minute warm-up at full load and with constant line, load and ambient conditions.

(5) The transient response is specified as the time required to settle from 50 to 75% step load change (rise time of step = 2µSec.) to a 1% error band.

(6) Dynamic response is the peak overshoot voltage during the transient response time defined in note 5 above.

(7) The input ripple rejection is specified for DC to 120Hz ripple with a modulation amplitude of 1% Vin.

(8) For module protection only, see also note 2.

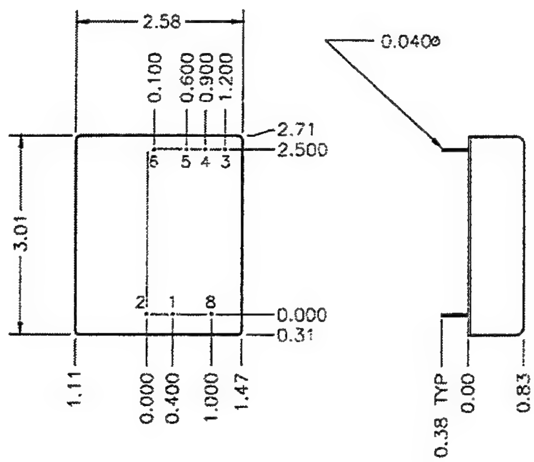
(9) The logic shutdown pin is Open Collector TTL, CMOS, and relay compatible. The input to this pin is referenced to input minus.

(10) The functional temperature range is intended to give an additional data point for use in evaluating this power supply. At the low functional temperature the power supply will function with no side effects, however, sustained operation at the high functional temperature will reduce expected operational life. The data sheet specifications are not guaranteed over the functional temperature range.

(11) The case thermal impedance is specified as the case temperature rise over ambient per package watt dissipated.

15 Watt SW Triple Series DC/DC Converters

General Specifications*			
All Models			Units
Logic Shutdown (9)			
ON Logic Level or Leave Pin open	MIN	2.4	VDC
OFF Logic Level	MAX	1.2	VDC
Input Resistance	TYP	10	k ohms
Converter Idle Current, Shut Down Pin Low	TYP	6	mA
Isolation			
Isolation Voltage 10μA Leakage Input-Output 12T & 24T Models	MIN	700	VDC
48T Models	MIN	1544	VDC
Input to Output Capacitance	TYP	190	pF
Environmental			
Case Operating Range No Derating	MIN	-25	°C
	MAX	80	°C
Case Functional Range (10)	MIN	-40	°C
	MAX	90	°C
Storage Range	MIN	-55	°C
	MAX	100	°C
Thermal Impedance (11)	TYP	4.4	°C/Watt
Thermal Shutdown Case Temperature	TYP	90	°C
General			
Unit Weight	TYP	7.0	oz
Mounting Kit		MS9	



BOTTOM VIEW SIDE VIEW

Mechanical tolerances unless otherwise noted:

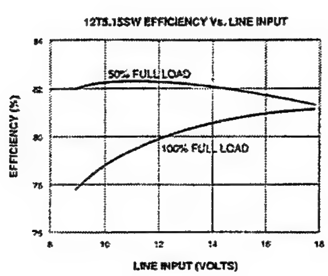
X.XX dimensions: ±0.020 inches

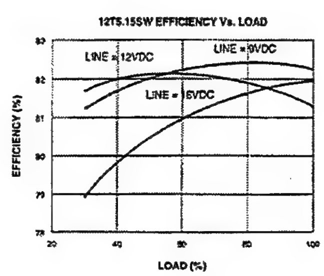
X.XXX dimensions: ±0.005 inches

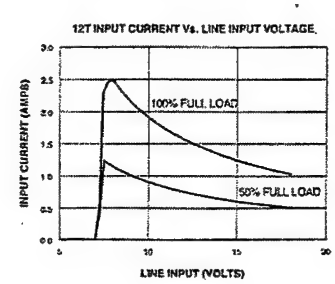
Seal around terminals is not hermetic. Do not immerse units in any liquid

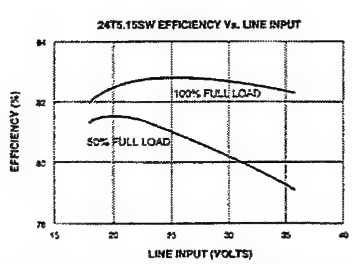
Pin	Function
1	+INPUT
2	-INPUT
3	+12/ +15 OUTPUT
4	CMN
5	-12/-15 OUTPUT
6	+5 OUTPUT
8	ON/OFF

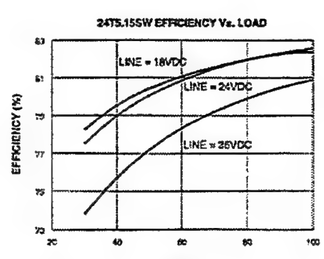
Typical Performance (Tc=25°C, Vin=Nom VDC, Rated Load).

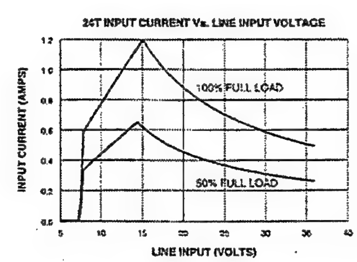












* Curves are applicable to both outputs ±12 and ±15 VDC

FreeWave Technologies, Inc.

Wireless RS232

Spread Spectrum Data Transceivers

The DGR-115 / 115H wireless rs232 spread spectrum data transceivers provide reliable long range data communications. Using the superior frequency hopping spread technology, FreeWave transceivers are capable of uncompressed data rates of 115.2 KBaud over distances of 20 miles or more, meeting the data communications needs in a wide variety of applications.

The DGR-115 / 115H product family operates at **1 Watt output power**, the maximum output power allowed under part 15 rules. As well as providing long range reliable data links, FreeWave transceivers set up quickly and incur no ongoing fees, unlike cellular and land line communications.

The FreeWave transceiver operates in either point to point or point to multipoint modes, selectable through any terminal program. Repeaters may be deployed in either mode to extend the range of the link, not by plugging two units in back to back as is the case with most radios, but by programming the DGR-115 to operate as a store and forward repeater. With up to two repeaters in a link and using optional external antennas, links of 60 miles and beyond are possible.

All transceivers are assigned a unique electronic serial number at the factory, providing complete control of who does and who does not have access to the data. An optional mode allows the transceiver to respond to a set of AT commands.

The DGR-115 and DGR-115H transceivers are manufactured at the FreeWave Technologies factory in Boulder, Colorado, where tight control is exercised to ensure consistent quality. Every unit shipped is tested from -40° C to +75° C, and must also pass real world data and link tests. FreeWave spread spectrum transceivers have been used on (to name but a few) tanks, aircraft, speed boats, yachts, race cars, and earth movers, and in environments ranging from offices to volcanoes to the Antarctic.

As a final note . . . is Frequency Hopping really better than direct sequence? We could have pages and pages of technical arguments expounding upon the merits of Frequency Hopping but the solution is really much more simple. The next time someone tries to tell you that their 900 MHz direct sequence modem is better than our 900 MHz hopper ask them to do a simple experiment: establish a link with the direct sequence modems, then set up a side by side parallel link with the FreeWave modems and watch what happens.

Technical Specifications

Item	Specification
Range*	20 Miles
RS232 Data Throughput **	1200 Baud to 115.2 KBaud
RS232 Interface	Asynchronous, Full duplex
System Gain	140 dB
Minimum Receiver Decode Level	-110 dBm @ 10-4 raw BER -108 dBm @ 10-6 raw BER
Operating Frequency	902 - 928 MHz
Modulation Type	Spread Spectrum, GFSK
Spreading Code	Frequency Hopping
Hop Patterns	15 (User Selectable)
Output Power	1 Watt (+30 dBm)
Error Detection	32 Bit CRC With Packet Retransmit
Antenna	3 Inch Whip Provided (DGR-115 Model) Non-standard SMA Connector Allows Use Of External Directional or Omni- Directional Antennas.
Power Requirements	10.5 - 18.0 VDC (AC Wall Adapter Provided)
Power Consumption	600 mA Transmit 100 mA Receive 180 mA Average
Connector	RS232 9 Pin Female, 9 Pin Male to 9 Pin Female Straight Through Cable Provided
Unit Address	Unique, Factory Preset
Operating Modes	Point to Point Point to Multipoint Store and Forward Repeater
Operating Environment	-40° C to +75° C
FCC Identifier	KNY-DGR-115
DOC (Canada) Identifier	2329 101 340A

CRYDOM

Control over power

Series 1-DC

7-40Amp • 0-500 Vdc • DC Output

- **MOSFET Output**
- **Low On-State Resistance**
- **Paralleling Capability for Higher Currents**
- **Panel Mount**

DC output relays feature MOSFET technology for low on-state resistance, assuring easy paralleling and switching capabilities to 40 amps at 100 Vdc. Lower current models are also available to 500 Vdc. All models come in Crydom's standard panel-mount package.

Manufactured in Crydom's ISO 9002 Certified facility for optimum product performance and reliability.

OUTPUT SPECIFICATIONS ①

MODEL NUMBERS	D1D07	D1D12	D1D20	D1D40	D2D07	D2D12	D4D07	D4D12	D5D07	D5D10
Operating Voltage Range [Vdc]	0-100	0-100	0-100	0-100	0-200	0-200	0-400	0-400	0-500	0-500
Max. Load Current ③ [Adc]	7	12	20	40	7	12	7	12	7	10
Min. Load Current [mA]	20	20	20	20	20	20	20	20	20	20
Max. Surge Current, [Adc] (10Msec)	15	28	42	106	22	27	17	36	19	29
Max. On-State Voltage Drop @ Rated Current [Vdc]	2.0	1.6	2.1	2.1	2.0	2.8	4.2	4.2	5.7	5.5
Thermal Resistance Junction to Case [$R_{\theta JC}$] °C/W	2.2	1.34	1.06	0.83	1.5	1.06	1.06	0.8	1.0	0.8
Max On-state Resistance @ Rated Current (R_{DS-ON}) [Ohms]	.29	.13	.10	.05	.29	.23	.6	.35	.8	.55
Max. Off-State Leakage Current @ Rated Voltage [mA]	0.1	0.2	0.3	0.3	0.1	0.3	0.3	0.3	0.2	0.3
Max. Turn-On Time [µsec]	100	100	100	100	100	100	100	100	100	100
Max. Turn-Off Time [msec]	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

INPUT SPECIFICATIONS ①

	DC CONTROL
Control Voltage Range	3.5-32 Vdc
Maximum Turn-On Voltage	3.5 Vdc
Minimum Turn-Off Voltage	1.0 Vdc
Nominal Input Impedance	See Note 4
Maximum Input Current	1.6 mA (5 Vdc), 28 mA (32 Vdc) ④

GENERAL NOTES

① All parameters at 25°C unless otherwise specified.

② Dielectric strength and insulation resistance are measured between input and output.

③ Heat sinking required, for derating curves see page 3.

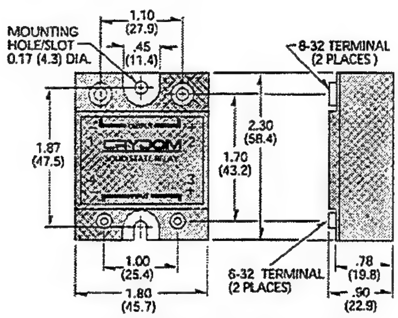
④ Input circuitry incorporates active current limiter.

GENERAL SPECIFICATIONS

Dielectric Strength 60Hz	2500 Vrms
Insulation Resistance (Min.) @ 500 Vdc	10^9 Ohm
Max. Capacitance Input/Output	50 pF
Ambient Operating Temperature Range	-30 to 80°C
Ambient Storage Temperature Range	-40 to 125°C

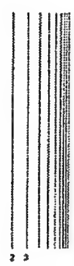
MECHANICAL SPECIFICATIONS

Weight: (typical)	3.0 oz. (86.5g)
Encapsulation:	Thermally Conductive Epoxy
Terminals:	Screws and Saddle Clamps Furnished, Unmounted



All dimensions are in inches (millimeters)

MAXIMUM SURGE vs. DURATION



Series 1-DC

7-40Amp • 0-500 Vdc • DC Output

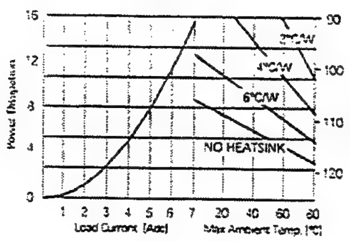
Crydom Heat Sinks offer excellent thermal management and are perfectly matched to the load current ratings of Crydom panel mount relays. Request Crydom's Heat Sink specification sheet for all the details.

CRYDOM

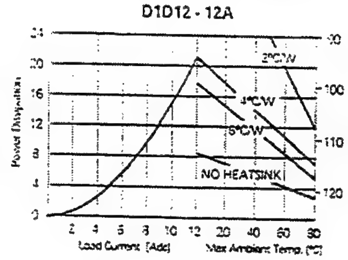
Control over power

CURRENT DERATING CURVES

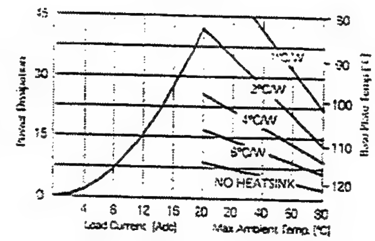
D1D07 - 7A



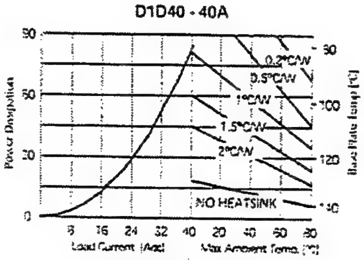
D1D12 - 12A



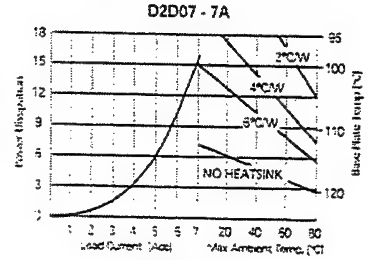
D1D20 - 20A



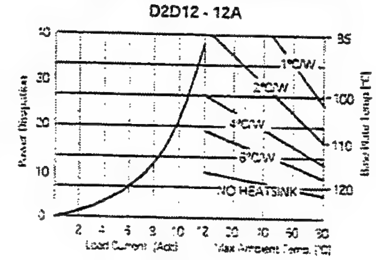
D1D40 - 40A



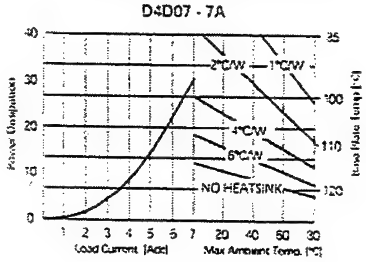
D2D07 - 7A



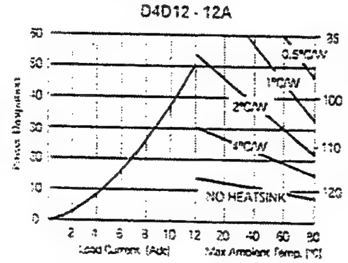
D2D12 - 12A



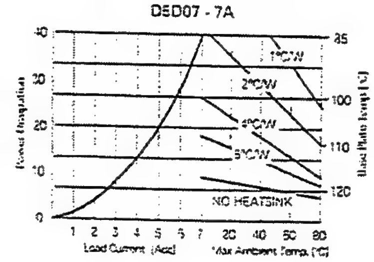
D4D07 - 7A



D4D12 - 12A



D5D07 - 7A



D5D10 - 10A

3-Phase Motor Data

Item	Parameter	Symbol	Units	5111	5112	5113
1	Continuous Torque (Stall)[1]	T_C	N·m	0.180	0.228	0.286
2	Peak Torque (Stall)	T_P	N·m	1.195	1.49	1.56
3	Friction Torque	T_F	N·m	3.0×10^{-3}	3.7×10^{-3}	4.0×10^{-3}
4	No-Load Speed	S_0	rad/s	515	360	278
5	Armature/Rotor Inertia	J_M	kg·m²	20.5×10^{-6}	26.9×10^{-6}	38.1×10^{-6}
6	Electrical Time Constant	T_E	ms	0.301	0.323	0.310
7	Mechanical Time Constant	τ_M	ms	8.70	6.50	6.20
8	Viscous Damping - Infinite Source Impedance	D	N·m/(rad/s)	13×10^{-6}	15×10^{-5}	17×10^{-6}
9	Damping Constant - Zero Source Impedance	K_D	N·m/(rad/s)	2.35×10^{-4}	4.15×10^{-4}	6.17×10^{-4}
10	Maximum Winding Temperature	θ_{MAX}	°C	155	155	155
11	Thermal Impedance	R_{TH}	°C/watt	3.2	3.0	3.0
12	Thermal Time Constant	τ_{TH}	min	15	19	25
13	Motor Weight	W_M	kg	0.60	0.80	0.95
14	Motor Constant	K_M	N·m/√W	48.5×10^{-3}	64.4×10^{-3}	78.6×10^{-3}
15	Motor Length	L	mm max	63.4	76.1	88.8

[1]Continuous torque specified at 25°C ambient temperature and without additional heat sink.

Model 5111 Winding Data (Other windings available upon request)

Item	Parameter	Symbol	Units	Winding 1	Winding 2	Winding 3	Winding 4
16	Reference Voltage	E	V	17.0	24.0	34.0	48.0
17	Torque Constant	K_T	N·m/A	33.5×10^{-3}	45.6×10^{-3}	67.0×10^{-3}	91.1×10^{-3}
18	Back-EMF Constant	K_E	V/(rad/s)	33.5×10^{-3}	45.6×10^{-3}	67.0×10^{-3}	91.1×10^{-3}
19	Resistance	R_T	Ω	0.51	0.883	2.04	3.520
20	Inductance	L	mH	0.130	0.266	0.525	1.06
21	No-Load Current	I_0	A	0.289	0.213	0.145	0.106
22	Peak Current (Stall)	I_P	A	33.33	27.18	16.66	13.63

Model 5112 Winding Data (Other windings available upon request)

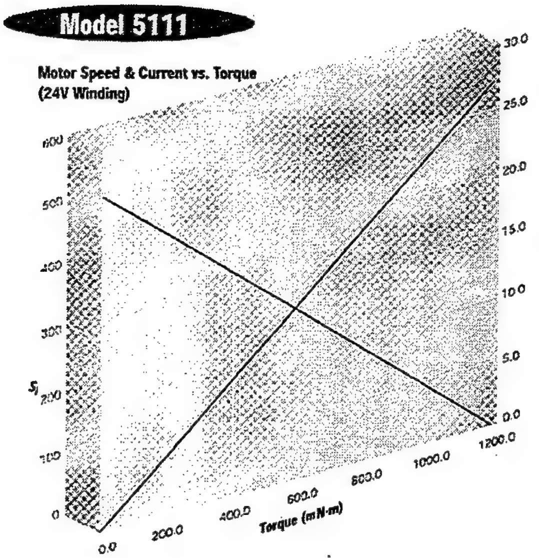
Item	Parameter	Symbol	Units	Winding 1	Winding 2	Winding 3	Winding 4
23	Reference Voltage	E	V	17.0	24.0	34.0	48.0
24	Torque Constant	K_T	N-m/A	47.0×10^{-3}	66.4×10^{-3}	94.0×10^{-3}	132×10^{-3}
25	Back-EMF Constant	K_E	V/(rad/s)	47.0×10^{-3}	66.4×10^{-3}	94.0×10^{-3}	132×10^{-3}
26	Resistance	R_T	Ω	0.533	1.06	2.13	4.25
27	Inductance	L	mH	0.172	0.342	0.686	1.370
28	No-Load Current	I_0	A	0.194	0.137	0.097	0.069
29	Peak Current (Stall)	I_P	A	32.0	22.6	15.9	11.3

Model 5113 Winding Data (Other windings available upon request)

Item	Parameter	Symbol	Units	Winding 1	Winding 2	Winding 3	Winding 4
30	Reference Voltage	E	V	17.0	24.0	34.0	48.0
31	Torque Constant	K_T	N-m/A	60.0×10^{-3}	86.5×10^{-3}	120×10^{-3}	173×10^{-3}
32	Back-EMF Constant	K_E	V/(rad/s)	60.0×10^{-3}	86.5×10^{-3}	120×10^{-3}	173×10^{-3}
33	Resistance	R_T	Ω	0.78	1.21	2.65	4.85
34	Inductance	L	mH	0.198	0.413	0.795	1.650
35	No-Load Current	I_0	A	0.152	0.105	0.076	0.053
36	Peak Current (Stall)	I_P	A	21.8	19.8	12.8	9.89

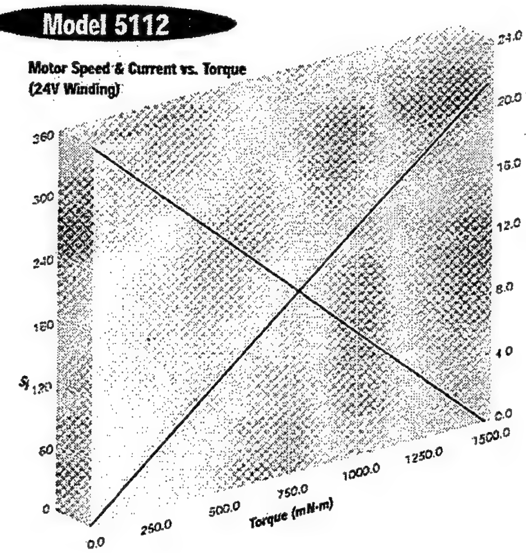
Model 5111

Motor Speed & Current vs. Torque
(24V Winding)



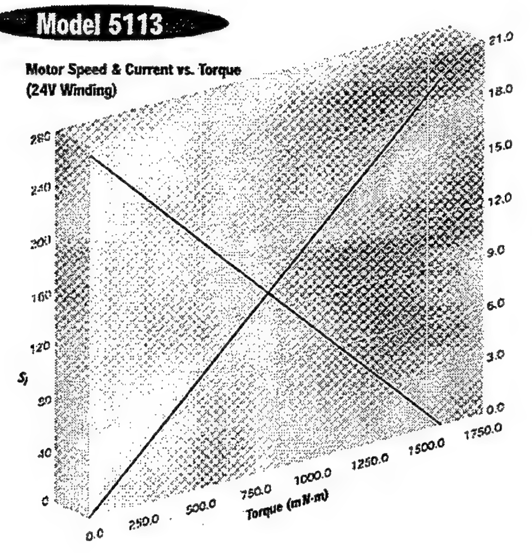
Model 5112

Motor Speed & Current vs. Torque
(24V Winding)

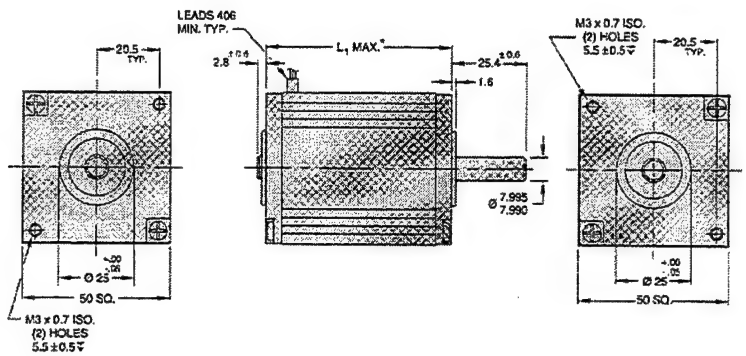


Model 5113

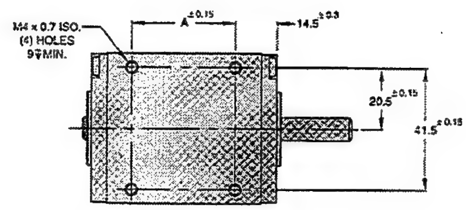
Motor Speed & Current vs. Torque
(24V Winding)



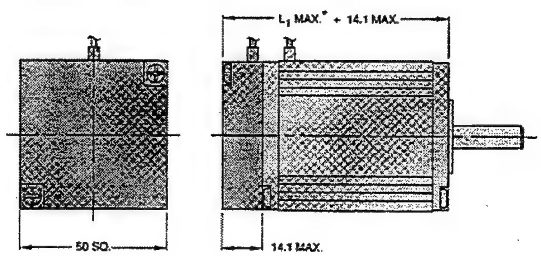
5100 Motor



Base Mounting Pattern



5100 Motor with Sensors



3-Phase Motor Connection Chart

FUNCTION	WIRE COLOR
PHASE A	BROWN
PHASE B	RED
PHASE C	ORANGE
SENSOR 1	GREY
SENSOR 2	BLUE
SENSOR 3	WHITE
HALL SENSOR POWER	VIOLET
HALL SENSOR POWER RETURN	BLACK

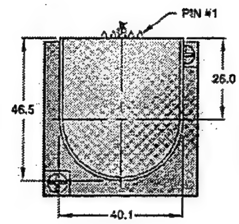
Base Lengths

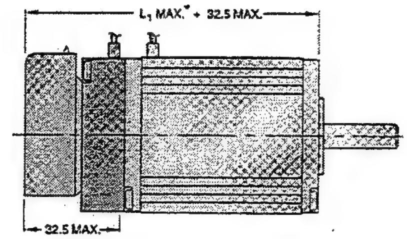
MODEL	A
[illegible]	35.0
[illegible]	47.5
5113	60.0

Notes:
- Unless otherwise specified, all tolerances are to be ±.005
- All measurements are in mm
- * See item 15 in motor data chart

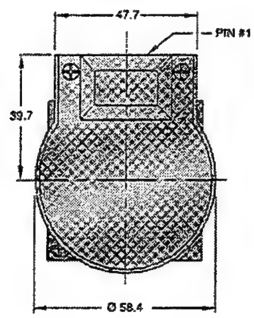
SERIES 5100

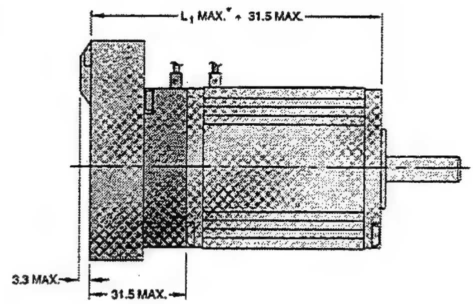
5100 Motor with Sensors and 91X0 Encoder



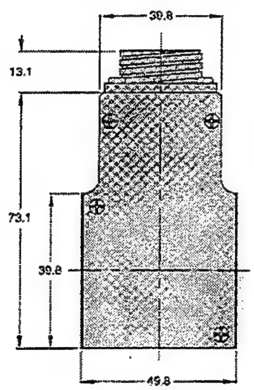


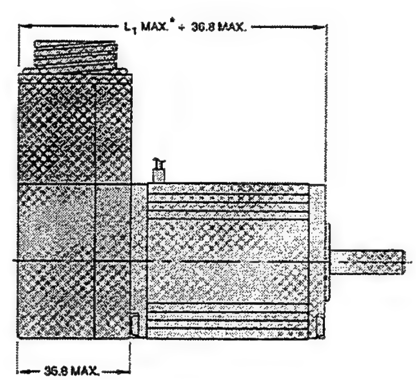
5100 Motor with Sensors and 90X0 Encoder





5100 Motor with Sensors, 91X0 Encoder and Connector





Motor, Encoder and Hall Sensor Connection Chart

PIN NO.	CONNECTION	PIN NO.	CONNECTION
1	PHASE A	9	+5 VDC
2	PHASE B	10	GROUND
3	PHASE C	11	CHANNEL A
4	NO CONNECTION	12	$\overline{\text{CHANNEL A}}$
5	SENSOR 1	13	CHANNEL B
6	SENSOR 2	14	$\overline{\text{CHANNEL B}}$
7	SENSOR 3	15	INDEX
8	NO CONNECTION	16	$\overline{\text{INDEX}}$

Encoder Connection Chart

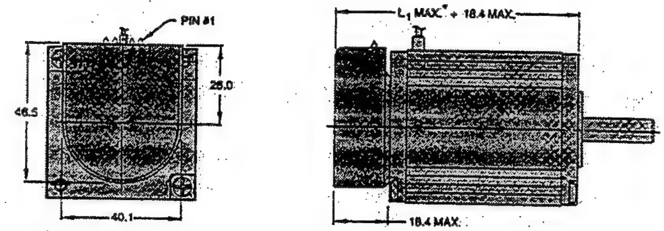
PIN NO.	COLOR	CONNECTION
1	BLACK	GROUND
2	GREEN	INDEX
3	YELLOW	CHANNEL A
[illegible]	RED	Vcc
5	BLUE	CHANNEL B

Notes:
- Unless otherwise specified, all tolerances are to be ±.005
- All measurements are in mm
- * See item 15 in motor data sheet

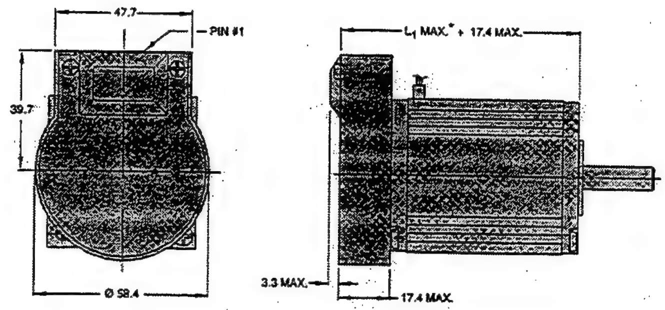
3-Phase Motor Connection Chart

FUNCTION	WIRE COLOR
PHASE A	BROWN
PHASE B	RED
PHASE C	ORANGE
SENSOR 1	GREY
SENSOR 2	BLUE
SENSOR 3	WHITE
HALL SENSOR POWER	VIOLET
HALL SENSOR POWER RETURN	BLACK

5100 Motor with 91X0 Encoder



5100 Motor with 90X0 Encoder



3-Phase Motor Connection Chart

FUNCTION	WIRE COLOR
PHASE A	BROWN
PHASE B	RED
PHASE C	ORANGE
SENSOR 1	[illegible]
SENSOR 2	BLUE
SENSOR 3	WHITE
HALL SENSOR POWER	VIOLET
HALL SENSOR POWER RETURN	BLACK

Encoder Connection Chart

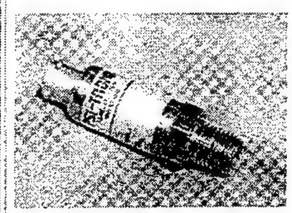
PIN NO.	COLOR	CONNECTION
1	BLACK	GROUND
2	GREEN	INDEX
3	YELLOW	CHANNEL A
4	RED	[illegible]
5	BLUE	CHANNEL B

Notes:
- Unless otherwise specified, all tolerances are to be ±.005
- All measurements are in mm
- * See item 15 in motor data chart

PSI-100
Millivolt Output Pressure Transducer

Photo & Features • Description • Basic Applications
Specifications • Dimensions • Options • Ordering Information

Accurate Measurement of Pressure Ranges of 15 to 10,000 psi



Features

- Low Cost
- Accuracy (Linearity, Hysteresis, Repeatability): ±.25% F.S. (B.F.S.L.)
- Hybrid Compensation Network for Reliability
- Standardized Output of 10 mV/V (other outputs available)
- Rugged All-Stainless Welded Construction

Description

Strain Gage Transducer With ±.25% Full Scale Accuracy (B.F.S.L.)

The PSI-100 offers pressure ranges of 0-15 to 0-10,000 psi, gage or absolute. High burst pressure, and a high accuracy of ±.25% Full Scale (B.F.S.L.) are featured.

The sensor consists of silicon piezoresistive strain gages mounted on a flat metal diaphragm, arranged in a wheatstone bridge configuration. The output is conditioned for 100 mV full scale output for all ranges (10mV/Volt).

The sensor, with hybrid compensation network is packaged in an all stainless steel housing for use in harsh environments.

Basic Applications

The PSI-100 is the economical answer for all general purpose pressure measurements where a cost-effective, high reliability unit is required. The small size (2 oz.), integrated hybrid compensation and rugged construction make this unit a good all purpose

transducer with an extremely long life for virtually all static and dynamic pressure measurement applications.

Specifications

PERFORMANCE

Standard Pressure Ranges: (gage or absolute)	0-15 to 10,000 psi
Overpressure:	2x full scale
Burst Pressure:	10x full scale or 20,000 psi whichever is less
Pressure Cavity Volume:	0.05 in^3
Output:	10mV/V ±1%
Accuracy (linearity, hysteresis, and repeatability):	±0.25% of full scale (B.F.S.L.)
Zero Balance:	±1.0% of full scale
Temperature Range: -0°F to 130° F Thermal Zero Shift: ±0.01% F.S./°F Thermal Sensitivity Shift: ±0.01% F.S./°F (±0.02% for optional temperature range or 316 S.S.)	
Resolution:	Infinite
Life:	10 Million cycles

ELECTRICAL

Excitation:	10VDC recommended [redacted]
Input Impedance:	1200Ω min.
Output Impedance:	Approx. 500Ω
Output/Input:	non-isolated, floating, 4-wire

ENVIRONMENTAL

Maximum Temperature Operating Range:	-65° F to +300° F
Compensated Range: **Optional Range:**	0°F to 130°F standard -40°F to 250°F optional

PHYSICAL

Weight:	2 ounces
Wetted Materials:	Stainless Steel 17-4 P.H. (316 S.S.T. optional) (no O-rings)
Media:	Compatible with 17-4P.H. or 316 S.S.T.
Connectors: Electrical Receptacle: Bendix PT1H-8-4 P or equivalent Mating Connector: Bendix PT06A-8-4S (SR) or equivalent (Mating connector not supplied)	

Dimensions

To view a graphical diagram simply select one of the options below. Upon completion of your viewing pleasure click on your browsers back button to return to this page.

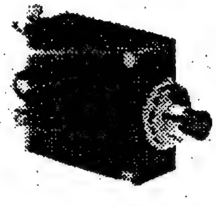
Side View
End View
Circuit View

Options

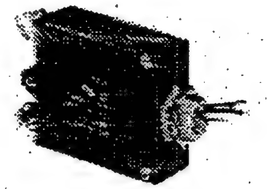
- Special Fittings, Outputs and Metric Ranges Available on Request
- Consult Factory for Custom Designs for Special Applications

Ordering Information

PSI-100	-	1000	-	G	-	1
MODEL NO.		PRESSURE Range (psi)		G=gage A=absolute		TEMP RANGE 1=0-130°F 2=-40°F TO +250°F



W23



W31

W23/W31 series

Toggle or Push/Pull Actuator Thermal Circuit Breaker

Features

- 0.5 amp to 50 amp ratings may be used as on/off switch.
- Cannot be reset against overload.
- W23 has visible trip indicator.
- Screw termination.
- Trip-free operation.

Agency Approvals

W23 and W31 are UL 1077 Recognized as Supplementary Protectors. File E69543, and CSA Certified as Appliance Component Protectors, File LR15734.

Electrical Data @ +25°C

Calibration: Will continuously carry 100% of rating, may trip between 101% and 134% of rating at 25°C. Must trip at 135% in one hour.

Maximum Operating Voltages: 50VDC or 250VAC (to 400 Hz).

Interrupting Capacity: 0.5-25 amp models — 2,500 amps at 50VDC, 1000 amps at 250VAC. 26-50 amp models — 1000 amps at 50VDC or 250VAC.

Resettable Overload Capacity: Ten times rated current.

Dielectric Strength: Over 1,500 volts RMS.

Current Rating In Amps	Maximum Resistance In Ohms ±30%
1	.61
5	.03
10	.01
15	.006
20	.004
30	.003
40	.002
50	.002

Mechanical/Environmental Data

Endurance Cycling: More than 6,000 cycles at 100% of rating, or 10,000 mechanical cycles.

Humidity: Will meet requirements of MIL-STD-202, Method 106.

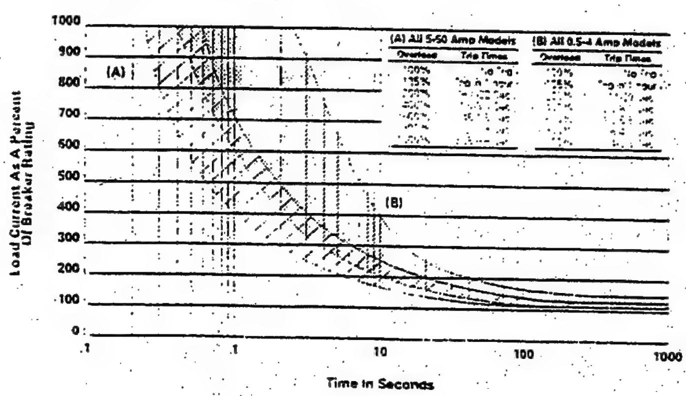
Salt Spray: Will meet requirements of MIL-STD-202, Method 101, Test Condition B.

Termination: Two #8-32 screw terminals.

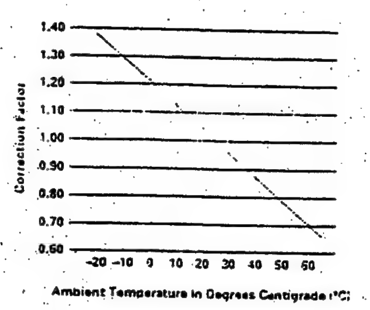
Mounting: W23 — Threaded bushing, 3/8" (9.53mm) diameter.
W31 — Threaded bushing, 15/32" (11.91mm) diameter, with or without anti-rotation flats.

Weight: Less than 2 oz. (57g).

Time Vs. Current Trip Curve @ +25°C



Ambient Compensation Chart



To use this chart: Read up from the ambient temperature to the curve, and across to find a correction factor. Multiply the breaker rating by the correction factor to determine the compensated rating. Calculate the overloads in terms of the compensated rating to use the published trip curve.

Typical Part No. ➤	W	23	-X	1	A	1	G	-5

1. Designator:
W = Circuit breaker

2. Series Number:
23 = Single pole, push/pull

3. Circuit Function:
X = Series trip

4. Button:
1 = Black with white amp rate marking and white trip band.

5. Mounting Bushing:
A = 3/8"-24 threaded bushing .375" (9.53mm) long, silver color

6. Terminals (See drawings for relative terminal positions):
1 = Screw terminals situated 90° to each other with #8-32 screws and washers installed.
3 = Screw terminals situtated parallel to each other pointing upward with #8-32 screws and washers installed.

7. Mounting Hardware:
A = Knurled nut/hex nut installed
G = Two hex nuts/lockwasher installed
Z = No mounting hardware supplied

8. Amp Rating:

0.5	3	7.5	20	35
1	4	10	25	40
2	5	15	30	50

Stock Items – The following items are normally maintained in stock for immediate delivery.

W23-X1A1G-1	W23-X1A1G-7.50	W23-X1A1G-25	W23-X1A1G-50
W23-X1A1G-2	W23-X1A1G-10	W23-X1A1G-30	
W23-X1A1G-3	W23-X1A1G-15	W23-X1A1G-35	
W23-X1A1G-5	W23-X1A1G-20	W23-X1A1G-40	

Ordering Information

Typical Part No. ➤	W	31	-X	2	M	1	G	-5

1. Designator:
W = Circuit breaker

2. Series Number:
31 = Single pole, toggle actuator

3. Circuit Function:
X = Series trip

4. Mounting Bushing:
1 = 15/32"-32 threaded bushing .320" (8.13mm) long, round, silver color
2 = 15/32"-32 threaded bushing .320" (8.13mm) long, double "D" silver color

5. Toggle:
M = Silver color metal toggle, round, with amp rate marking on end

6. Terminals (See drawing for relative terminal positions):
1 = Screw terminals situated 90° to each other with #8-32 screws and washers installed.
5 = Screw terminals situated parallel to each other pointing downward with #8-32 screws and washers installed.

7. Mounting Hardware:
A = Knurled nut/hex nut intalled
G = Two hex nuts/lockwasher installed
Z = No mounting hardware supplied

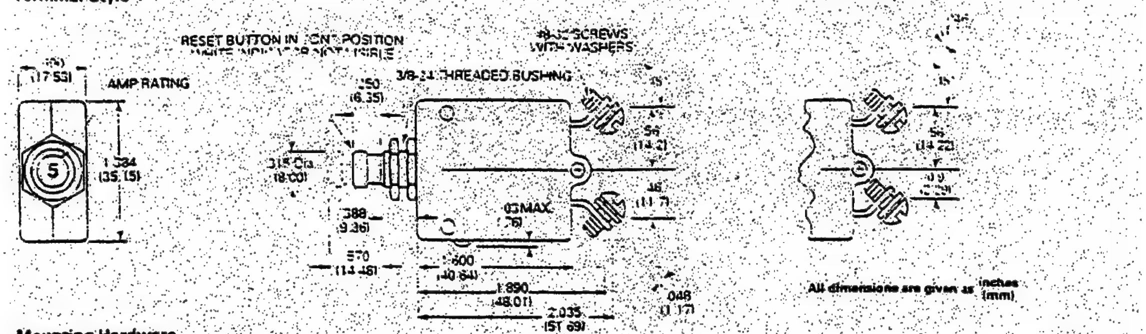
8. Amp Rating:

0.5	3	7.5	20	35
1	4	10	25	40
2	5	15	30	50

Stock Items – The following items are normally maintained in stock for immediate delivery.

W31-X2M1G-1	W31-X2M1G-10	W31-X2M1G-35
W31-X2M1G-2	W31-X2M1G-15	W31-X2M1G-40
W31-X2M1G-3	W31-X2M1G-20	W31-X2M1G-50
W31-X2M1G-5	W31-X2M1G-25	
W31-X2M1G-750	W31-X2M1G-30	

Terminal Style 1 **Terminal Style 3**

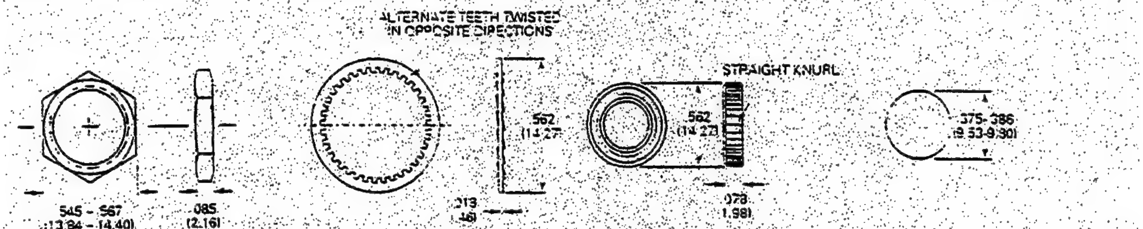


Mounting Hardware **Suggested Mounting Holes**

Hex Nut
(55-001D - Silver Color)

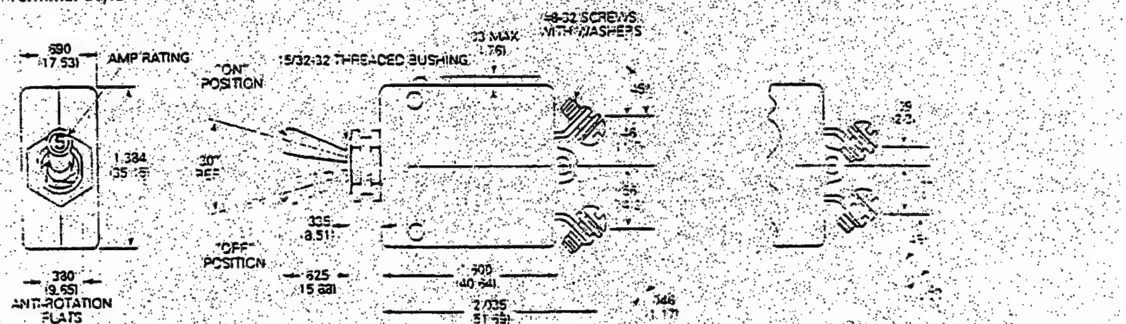
Lockwasher

Knurled Nut
(55-008A - Silver Color)



W31 Outline Dimensions

Terminal Style 1 **Terminal Style 5**

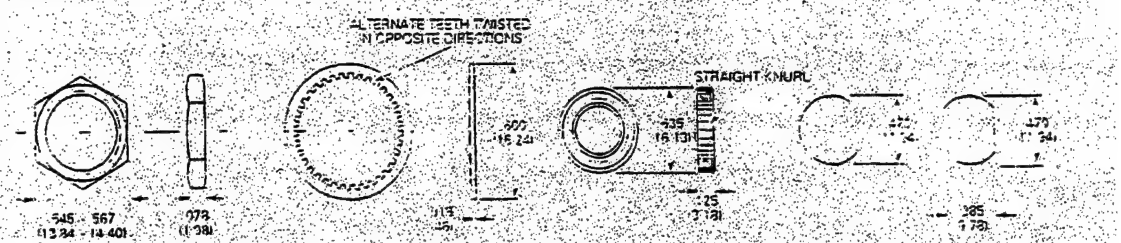


Mounting Hardware **Suggested Mounting Holes**

Hex Nut
(55-001B - Silver Color)

Lockwasher
88-002B - Silver Color

Knurled Nut
55-010B - Silver Color



W58 series

Push To Reset Only Thermal Circuit Breaker

Features

- 0.5 amp to 35 amp ratings.
- Cannot be manually tripped.
- Button extends for visual trip indication.
- Push button to reset breaker.
- Termination is screw or .250" QC.

Agency Approvals

W58 Series is UL 1077 Recognized as Supplementary Protectors, File E69543, and CSA Certified as Appliance Component Protectors, File LR15734.

Electrical Data @ +25°C

Calibration: Breaker will continuously carry 100% of rated load. It may trip between 101% and 145% of rated load, but must trip at 145% at 25°C.
Dielectric Strength: Over 1,500 volts RMS.
Maximum Operating Voltages: 50VDC; 250VAC.
Interrupt Capacity: 2,000 amps at 50VDC (0.5 - 35 amp models).
1,000 amps at 250VAC (0.5 - 35 amp models).
Note: 30 and 35 amp models not UL or CSA.
Resettable Overload Capacity: Ten times rated current.

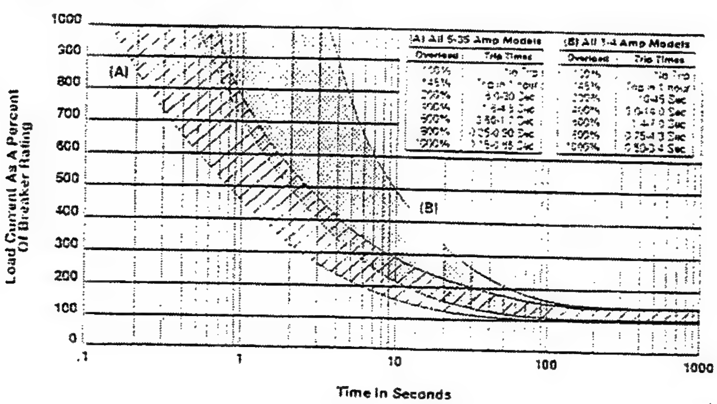
Maximum Resistance vs. Current Rating @ +25°C

Current Rating in Amps	Maximum Resistance in Ohms	Current Rating in Amps	Maximum Resistance in Ohms
0.5	5.0	7	0.020
0.75	2.5	8	0.020
1	1.35	9	0.020
1.5	0.75	10	0.014
2	0.32	12	0.010
2.5	0.25	15	0.010
3	0.18	20	0.008
3.5	0.15	25	0.005
4	0.10	30	0.004
5	0.026	35	0.004
6	0.026		

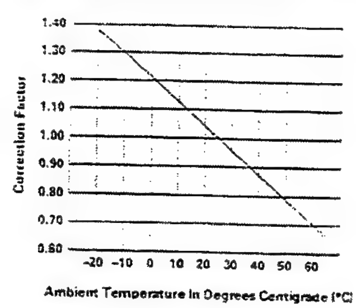
Mechanical/Environmental Data

Shock: Withstands to 10g.
Endurance Cycling: Over 1,000 cycles at 200% of rated load.
Vibration: Withstands to 10g at 10-55 Hz.
Weight: Less than 1 1/2 oz. (42.5g).

Time vs. Current Trip Curve @ +25°C



Ambient Compensation Chart



To use this chart: Read up from the ambient temperature to the curve, and across to find a correction factor. Multiply the breaker rating by the correction factor to determine the compensated rating. Calculate the overloads in terms of the compensated rating to use the published trip curve.

Typical Part No. ▶	W	58	-X	B	1	A	4	A	-5

1. Designator:
W = Circuit breaker

2. Series Number:
58 = Single Pole, Push-to-Reset

3. Circuit Function:
X = Series Trip

4. Button:
A = White, plain, no rate marking, no trip band
B = White with red rate marking, red trip band
C = White with black rate marking, red trip band
E = White with red rate marking no trip band
F = White with black rate marking, no trip band

5. Mounting Bushing:
1 = 7/16" x .500" (12.70mm) long
4 = 15/32" x .300" (7.62mm) long, black
6 = 3/8" x .465" (11.81mm) long, round

6. Terminals:
A = Quick connect .250" (6.35mm) straight
B = Quick connect .250" (6.35mm) 90°
C = 6/32 screw 90° (screws installed)
D = 6/32 screw 90° (screws bulk packed)

7. Mounting Hardware:
4 = Knurled nut/hex nut
6 = Knurled nut/hex nut/lock washer
12 = Knurled nut/lock washer
15 = Two hex nuts/lock washer
99 = No mtg. hardware supplied (Use C, Step #8)

Note: For other hardware combinations, order separately. See mounting hardware Ordering Information table.

8. Mounting Hardware Packaging:
A = Assembled to bushing
B = Bulk unassembled
C = No mounting hardware

9. Specify Amp Rating:

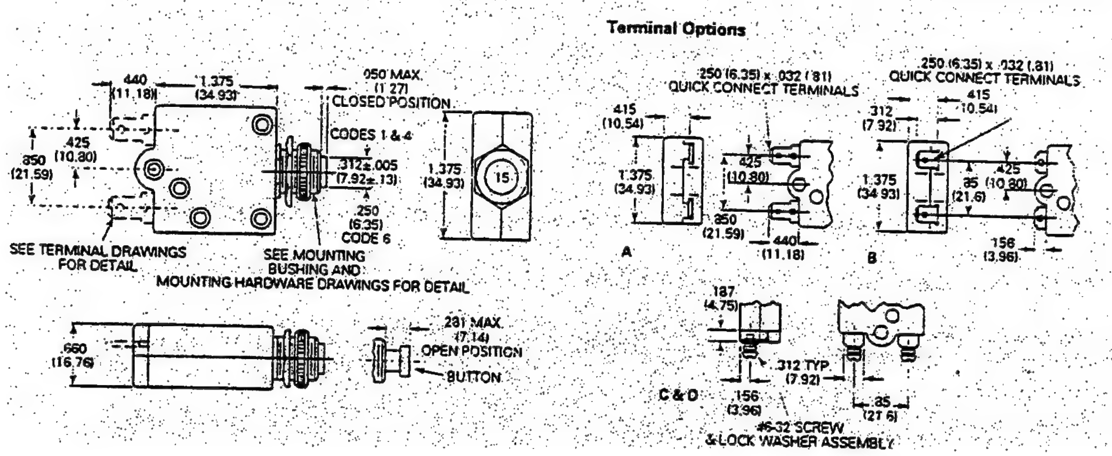
0.5	1.5	3	5	8	12	25
0.75	2	3.5	6	9	15	30*
1	2.5	4	7	10	20	35*

*Not UL or CSA

Stock Items – The following items are normally maintained in stock for immediate delivery.

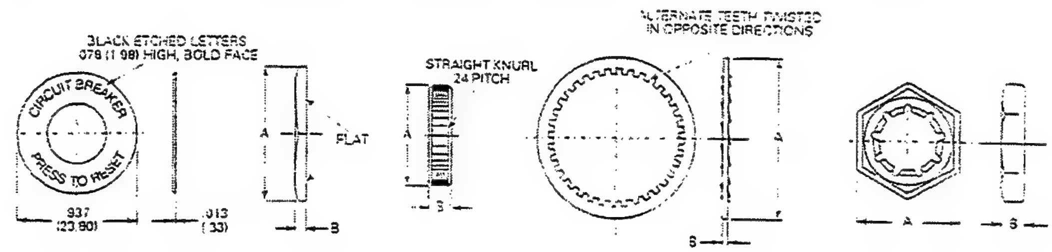
W58-XB1A4A-1	W58-XB1A4A-6	W58-XB1A4A-15	W58-XC4C12A-1	W58-XC4C12A-10
W58-XB1A4A-2	W58-XB1A4A-7	W58-XB1A4A-20	W58-XC4C12A-2	W58-XC4C12A-15
W58-XB1A4A-3	W58-XB1A4A-8	W58-XB1A4A-25	W58-XC4C12A-3	W58-XC4C12A-20
W58-XB1A4A-4	W58-XB1A4A-10	W58-XB1A4A-30	W58-XC4C12A-5	W58-XC4C12A-25
W58-XB1A4A-5	W58-XB1A4A-12	W58-XB1A4A-35	W58-XC4C12A-7	W58-XC4C12A-30

Outline Dimensions



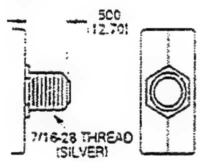
Mounting Hardware

Disc | Hex Nut | Knurled Nut | Lockwasher | Pal Nut

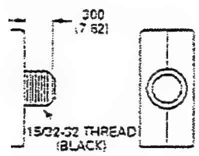


Mounting Bushing

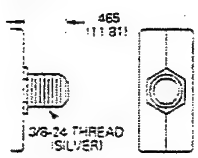
Type 1



Type 4



Type 6



Mounting Hardware Dimensions

	Dim.	Hex.	Knurled	L/W	Pal
A.	3/8"	.556	.562	.562	.562
	7/16"	.625	.625	.540	.625
	15/32"	.556	.625	.600	.625
B.	3/8"	.085	.078	.018	.140
	7/16"	.078	.125	.022	.111
	15/32"	.078	.125	.018	.090

Mounting Hardware Ordering Information

Mounting Bushing Code	Knurl Nut	Hex Nut	Pal Nut	Washer	Push to Reset Disc
1	55-010A	55-011A	16S086B	88-021B	33-012A
4	*	55-001B	16S086C	88-002A	33-012C
6	55-008A	55-001D	16S086A	88-006K	33-012B

* 55-010B (silver) 55-010E (black)

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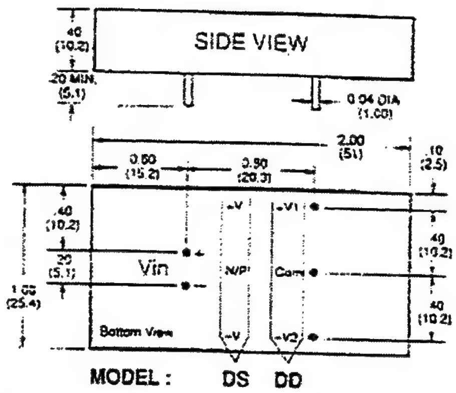
• How to Interpret Pin Assignments



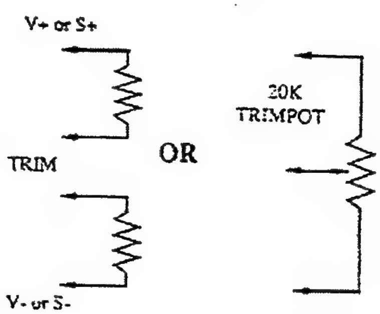
Every model has a physical dimension drawing associated with its data sheet. The pin assignments for each variation of the model is shown on the physical dimension diagram. The proper pin assignments are printed above the model as shown by the arrows above.

• Using the Shut Down Control

Most of our converters are available with shut down control. This control gives the designer the flexability to disable the converter with a open collector signal. In order to disable the converter, a low (0.5 mA sink) can be applied to the shut down terminal. A high will enable the converter again. In applications where no shut down control is needed, the shutdown terminal can be left floating and the converter will operate normally.

Shut down control is an option for model F. Add an "S" suffix to the part number to get this option.

• Suggested Output Trim Circuit



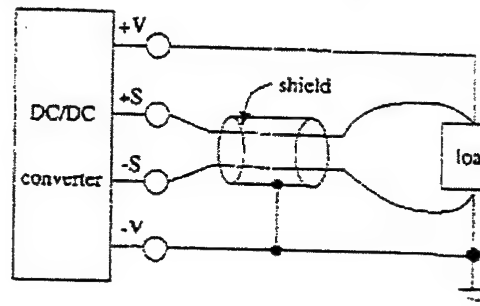
Converters that have sense terminals should have the trim resistors connected to te sense terminals. Other models can be connected to V+ or V-.

• Using the Sense Terminals

Some applications of DC/DC converters require that the load be located some distance from the converter. In these situations, the output from the converter may not meet the load regulation specification. This is caused by the voltage drop in the wiring going to the load. However, this drop can be compensated for by using the sense pins available on our higher power converters.

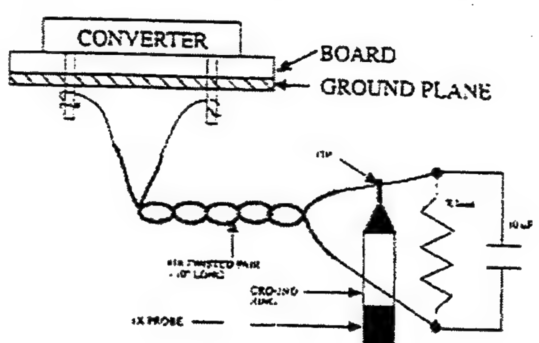
There is a sense terminal for each output designated +S and -S. These terminals, when connected to the load, compensate for the voltage drop in the output leads. It is important that the sense and the load leads be approximately the same length.

In applications where the load is located close (< 1.0") from the converter, the sense leads should be shorted to their respective output in order to meet published specifications.



• Suggested Ripple Measurement

The true ripple can be measured using the figure below. Using a twisted pair at 3 twists per inch connected to a 10 µF capacitor, this technique eliminates "Common Mode Noise". Using the probe tip ground instead of the leaded "alligator clip" ground reduces noise pick up.



SPECIFICATIONS
All Specifications Typical @ 25°C, Nominal Line, and Full Load Unless Otherwise Noted.

ABSOLUTE MAXIMUM RATINGS
Input Voltage 58Vdc
I/O Isolation Voltage .... 500V Continuous, 1000V <1 Sec.
Operating Case Temperature .... +95°C
Storage Temperature .... +105°C

INPUT SPECIFICATIONS
Input Voltage Range .... 36 to 75Vdc
Nominal Input Voltage 48Vdc
Maximum Input Current .... 4.96A @ 36Vin
Maximum Inrush Current (0 to 75V) .... 30A, max.
Input Filter .... Π (PI) Filter
Remote Shut/Down Control
  On Control .... TTL High or Open Circuit
  Off Control .... < 1.8Vdc
Input Line Fuse Required

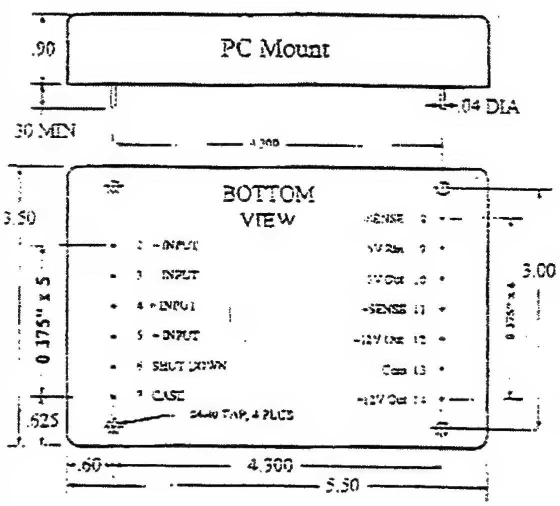
OUTPUT SPECIFICATIONS
5V .... 1 to 10A, ±1%
  Ripple & Noise, 20MHz BW 50mVp-p, 10mVrms
  Output Overvoltage Clamp .... 6.2V±5%
±12V (with Balanced Loads) .... 0.2 to 2.0A, ±1%*
  Ripple & Noise, 20MHz BW 50mVp-p, 10mVrms
  Output Overvoltage Clamp (+12V to -12V) .... 28V±5%
* For ±12V Output unbalanced loading application, please specify model R100T4805T12.

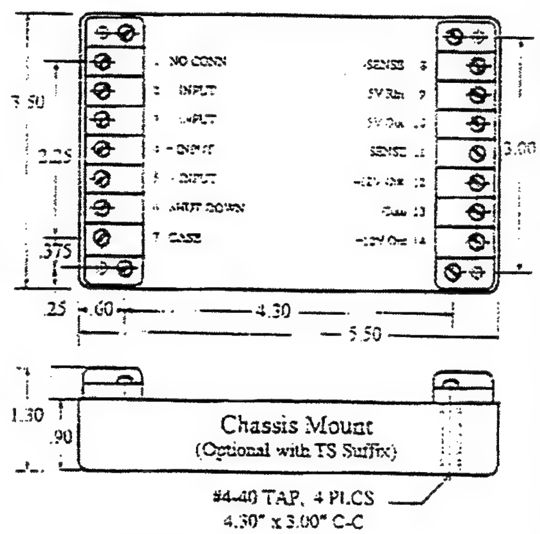
Output Power .... 100Watt, max.
Line Regulation, LL to HL .... ±0.5%, max.
Load Regulation .... ±0.5%, max.
Temperature Coefficient .... ±0.02%/°C, max.

GENERAL SPECIFICATIONS
Efficiency, FL .... 82%, min.
Isolation Voltage, Input to Output .... 500Vdc, min.
Isolation Capacitance .... 0.0001µF, typ.
Isolation Resistance .... 1MΩ, min.
Switching Frequency .... 100KHz, min.

ENVIRONMENTAL SPECIFICATIONS
Operating Case Temperature .... −25°C to +85°C
Storage Temperature Range .... −55°C to +105°C
Thermal Resistance .... 2.2°C/Watt Dissipate
Derating .... Required to keep +85°C max. case temperature
Humidity .... 20-95% R.H. (Noncondensing)
Cooling .... Free Air Convection

PHYSICAL SPECIFICATIONS
Dimensions (PC Mount) .... 3.5" x 5.5" x 0.90"
Dimensions (Chassis Mount) .... 3.5" x 5.5" x 1.30"
Weight .... 16 OZ. (450g.)
Case Material .... Black Coated Metal
(PC Mount unit Non-Conductive Seating Surface)





LTR	Description	Date

Unless Otherwise Specified:
Dimensions are in inches
Tolerances:
Decimals .xx ± .020
.xxx ± .005
Fractions ±

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Tel: 508/230-8022 ; Fax: 508/230-2371

Model No. **R100T4805-12**

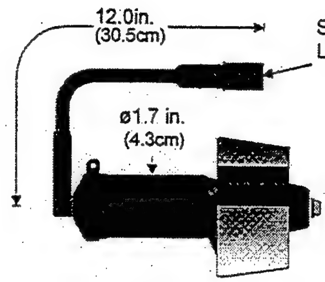
Rev 1 | Date 6/21/99 | Sh 1 of 1

Model 250

DC BRUSHLESS THRUSTERS

- ¼hp thruster with 5kg forward thrust ideally suited for small ROV's & other subsea applications.
- DC brushless rare earth motor for maximum reliability, high efficiency & high power.
- Power & control electronics housed within motor case for reliability & simplified installation.
- Nylon propeller & Nylon Kort nozzle for high Bollard thrust & open water efficiency.
- Magnetic propeller coupling for 750 meter depth rating without shaft seals. 1,500 meter and full ocean depth (with oil-filled housings) ratings also available.
- High RPM, low inertia motors coupled to planetary gear reduction units yield lightweight & compact designs at a very affordable price.
- Custom configurations include alternate voltages, subsea connectors, power ratings, mountings & depth ratings as well as open (unducted) propellers, etc.

SCALE 1:4

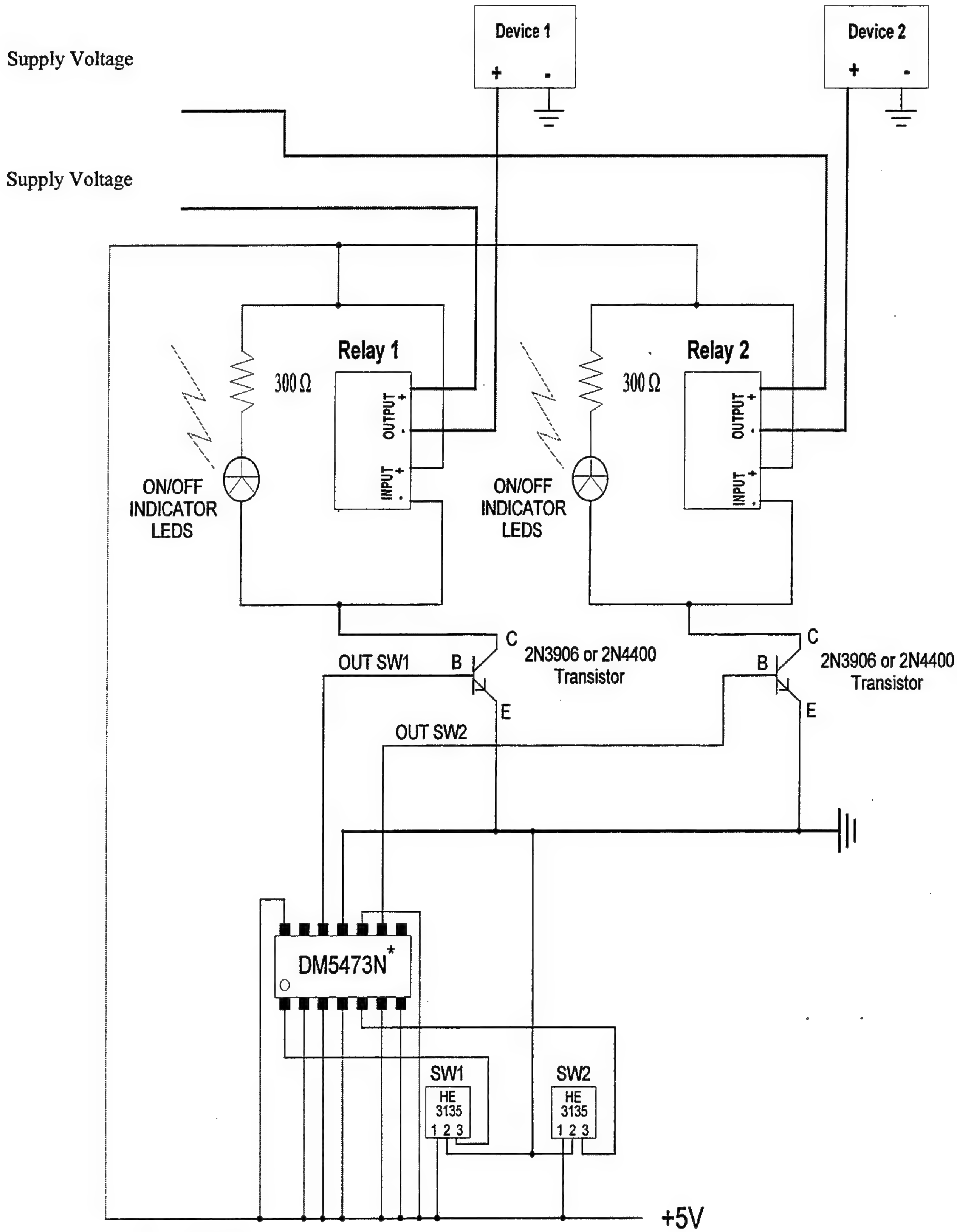


Bollard Output	*Input*	*Weight*	*Depth*
12 lbf (5.4 kg) forward 6 lbf (3.6 kg) reverse	145 VDC, 1.9 A power Power ground +12 V electronics power ±5 V command signal Signal ground Other voltages optional	2.0 lb (0.9 kg) in air 1.5 lb (0.7 kg) in water	2,500 ft (750 m) standard 5,000 ft (1,500 m) & full ocean depth (oil-filled) optional

Specifications subject to change without notice

APPENDIX C

Magnetic Switch System Scheme



Supply Voltage
Supply Voltage
Device 1
Device 2
+ -
+ -
Relay 1
Relay 2
300 Ω
300 Ω
OUTPUT
INPUT
OUTPUT
INPUT
ON/OFF INDICATOR LEDS
ON/OFF INDICATOR LEDS
C
B
E
2N3906 or 2N4400 Transistor
2N3906 or 2N4400 Transistor
OUT SW1
OUT SW2
DM5473N*
SW1
HE 3135
1 2 3
SW2
HE 3135
1 2 3
+5V

* Or DM7473

LIST OF REFERENCES

Brutzman, Donald P., *A Virtual World for an Autonomous Undersea Vehicle*, Ph.D. Dissertation, Naval Postgraduate School, Monterey, CA, December 1994. Available at http://web.nps.navy.mil/~brutzman/dissertation/

Brutzman, D. P., *NPS Phoenix AUV Software Integration and In-Water testing*, AUV 96, Monterey, CA, June 1996.

Healey, A. J., *Research on an Autonomous Vehicle at the Naval Postgraduate School*, Naval Research Reviews, Office of Naval Research, Washington, D.C., Volume XLIV, Number 1, Spring 1992.

Marco, D. B., *Autonomous Control of Underwater Vehicles and Local Area Maneuvering*, Ph.D. Dissertation, Naval Postgraduate School, Monterey, CA, September 1996.
Available at http://www.cs.nps.navy.mil/research/auv

Dana F, Geiger, *Phaselock loops for DC Motor speed control,* 1981

James B. Dabney, Thomas L. Harman, *Mastering Simulink 2,* 1998 Matlab Curriculum Series

Chee-Mun Ong, School of Electrical & Computer Engineering, *Dynamic simulation of electric machinery using Matlab/Simulink,* 1998

Kevin A. Torsiello, *Acoustic Positioning of the NPS Autonomous Underwater Vehicle during hover conditions*, March 1994

The MATHWOKS Inc., *Simulink: Dynamic System Simulation for MATLAB*, Using Simulink Version 2.

Microsoft, *User's Guide for Microsoft Project 98, Complete Project Communication and Control,* 1998. Available at http://www.microsoft.com/project/

Electric and Hybrid Vehicle (EHV) National Data Center (NDC)
Available at http://www.ev.hawaii.edu:80/

Pittman, Electric Motor Manufacturer
Available at http://www.pittmannet.com/

DC/DC Conveter Calex,
Available at: http://www.calex.com/

Circuit breaker, series W58, from SIEMENS:
Available at: http://www.execpc.com/industrialelectronics/potter/pbw58.html

http://www.sontek.com/about.htm
Available at: http://www.tritech.co.uk/

Batteries 12 V DC Lifeline
Available at: http://www.dcbattery.com/lifeline_agm.html

FreeWave Technologies, wireless data modems
Avalaible at: http://www.freewave.com/

RD Instruments (RDI), Acoustic Doppler Current Profilers (ADCP)
Avalaible at: http://www.rdinstruments.com/home.html

SonTek, Inc. SonTek, Doppler current meters
Available at: http://www.sontek.com/

PSI-TRONIX guages and transducers that accurately measure
Available at: http://www.psi-tronix.com/

DGPS and GPS products
Available at: http://www.Motorola.com

Servo amplifier BE30A8, Advanced Motion Control
Available at: http://www.a-m-c.com

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